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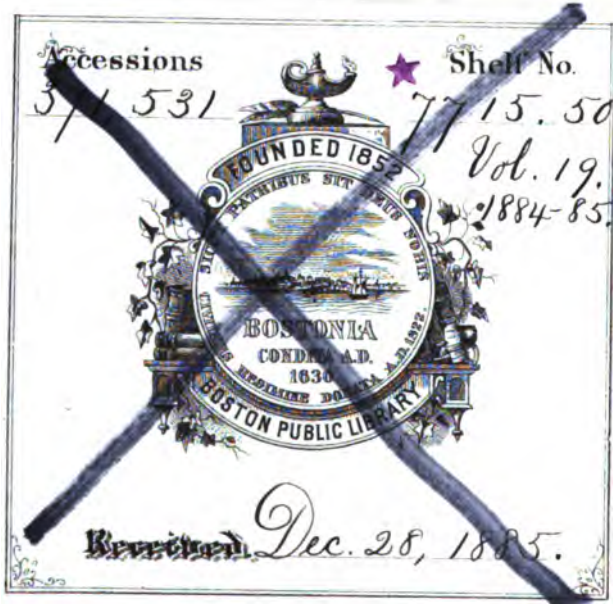
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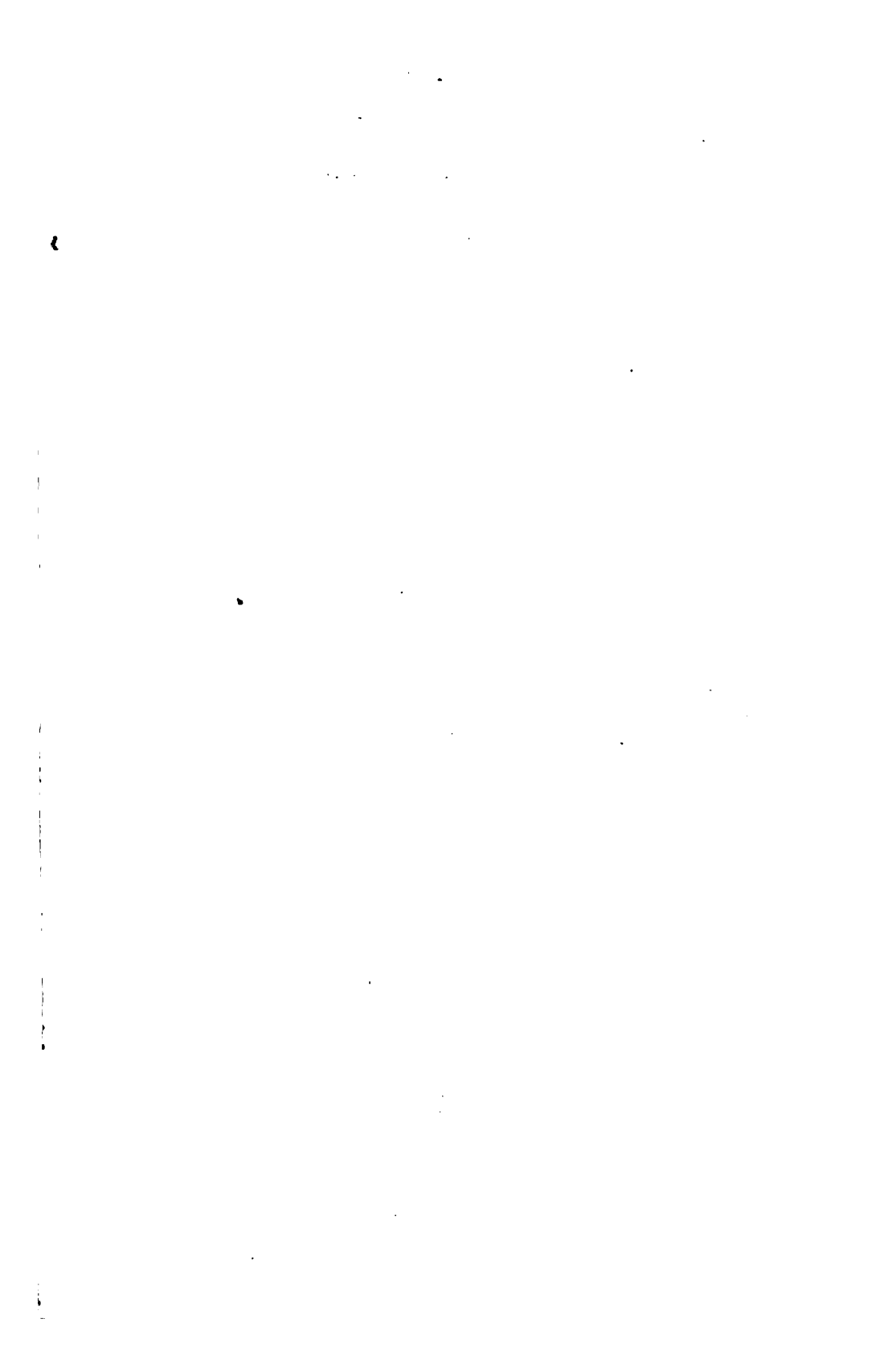
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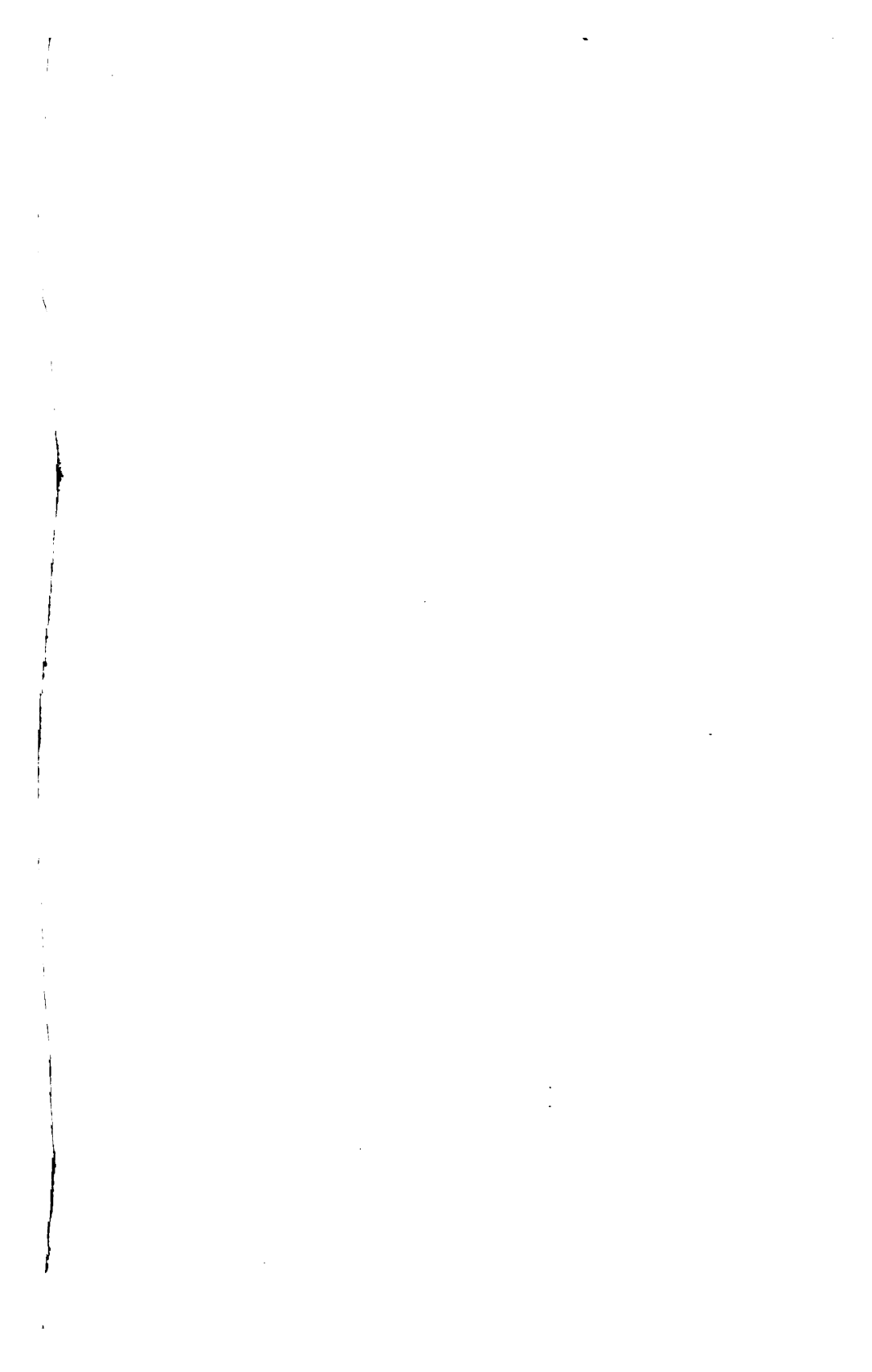
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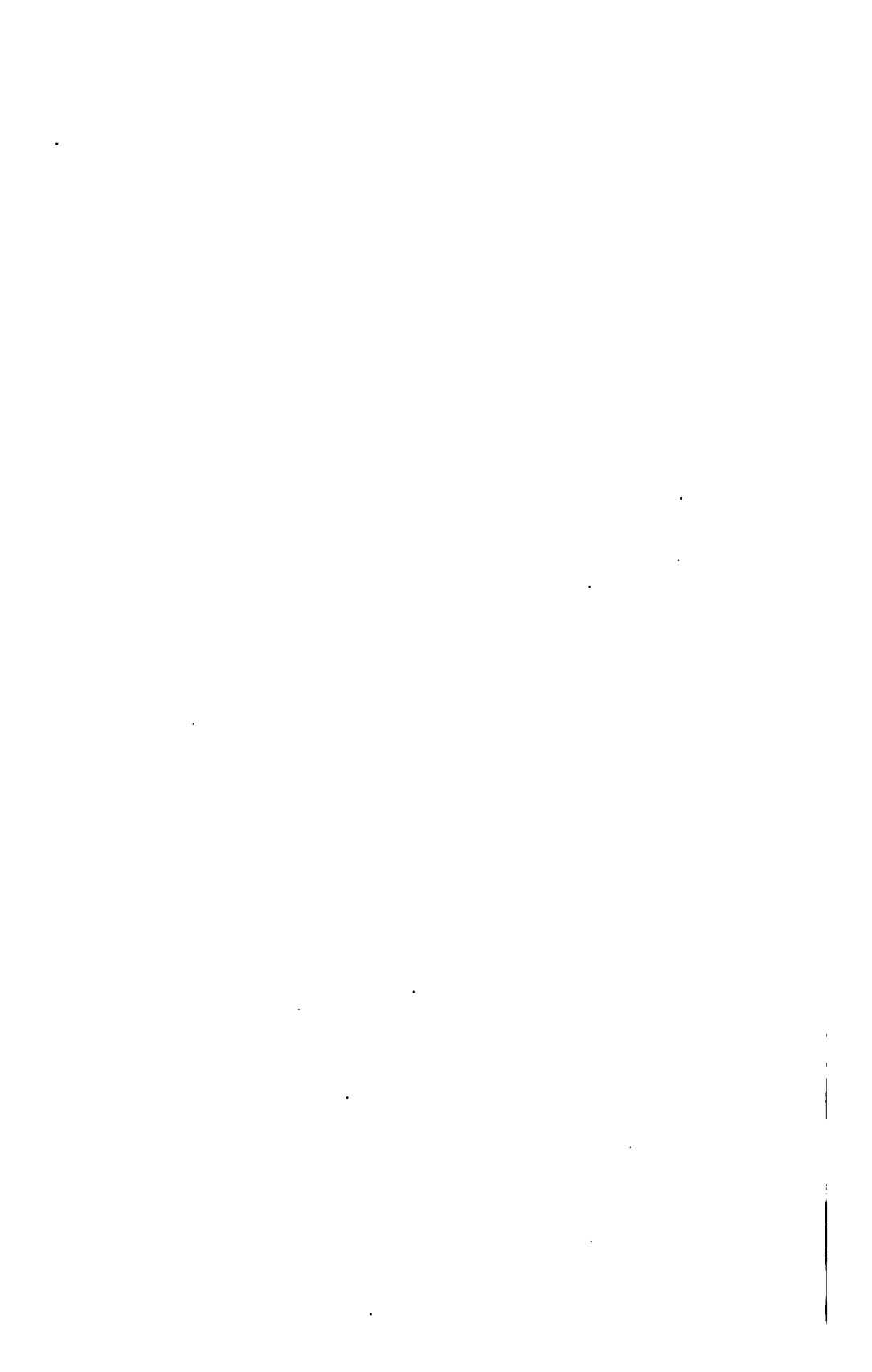
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NORMAL AND PATHOLOGICAL.

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Journal of Anatomy and Physiology.

ON THE HISTOLOGY OF THE VITREOUS HUMOUR.

BY ARTHUR C. YOUNAN, M.B., C.M., *Vans Dunlop Scholar*,
University of Edinburgh. (PLATES I. and II.)

FEW subjects in histology have been the occasion of so much difference of opinion as the structure of the vitreous humour of the eye. The tissue is so transparent, its structural element so delicate and difficult to observe under the microscope, that so much variance in opinion is scarcely surprising. The great diversity of views entertained by different authors is also, in part, explicable on the ground that they resorted to artificial hardening, which in great part alters both the macroscopic and microscopic appearances of the vitreous.

It is admitted by all that the vitreous consists of a solid and a fluid part. The nature of both has been disputed, but especially that of the solid part, and also its arrangement. Pappenheim (1842, quoted in *Op.* 1, p. 348) found that, on hardening the vitreous with carbonate of potash, the stroma appeared to be composed of laminae running parallel with the surface, each lamina consisting of fine fibres and a homogeneous matrix. Brücke (1843, *Op.* 2, p. 346) removed the sclerotic, choroid, and retina from the eye of a sheep as far forward as the ora serrata, and placed the exposed vitreous in a concentrated solution of diacetate of lead. After some hours he made sections of the vitreous thus hardened, and observed concentric white lines parallel with the general surface, and presenting on section the appearance of finely striped agate. He found that the vitreous so prepared tore easily in the direction of the layers, which appeared to him to consist of milky transparent membranes with intervening clear spaces filled by an apparently

gelatinous mass. In a later communication (1845, *Op.* 2, p. 130), he gave the results of an examination of the frozen but otherwise normal vitreous, which confirmed him in his opinion that the vitreous mainly consists of a series of concentric membranes. Hannover (1845, *Op.* 2) hardened the vitreous by immersion in a solution of chromic acid for some months, and found, in the case of the dog, cat, ox, and sheep, that when the eye is divided by a median transverse incision, the vitreous shows a concentric lamination similar to that of an onion. But in the case of the human vitreous hardened in the above manner, he found a series of segments or rays, somewhat like those of an orange, radiating from near the axis of the eye, where the hyaloid canal exists in the fœtus. Hannover's observations were repeated by Bowman (1849, *Op.* 3, p. 97). He placed human eyes in a straw-coloured solution of chromic acid, and found, on slicing the hardened eyes longitudinally and transversely, a series of concentric lines in the outer third of the vitreous. "The lines were parallel to the retina and could in some instances be traced quite round the section, but in no case did these circular lines extend more than about a third of the distance from the retina to the centre of the vitreous, and when they ceased, they were replaced by others of a straight or slightly waved character, which had more or less of a convergent direction towards the centre. In the centre, in all the specimens, was an irregular cavity of variable size, apparently formed by breaking up of the tissue" (*Op. cit.* p. 98). A slight touch with a pin was sufficient to tear the vitreous in the direction of these lines and to convert the laminae into separate sheets. "Several of the outer layers run towards the ciliary body, and there seemed to approach the very surface of the vitreous near the ora serrata, probably uniting with the hyaloid membrane in contact with the zonule of Zinn as described by Brücke. Those layers next within bend inwards towards the margin and back of the lens, of course behind the canal of Petit, and appear rather to cease in succession at the surface of the lens than to be continued concentrically behind it, though on this point the preparations do not speak positively." He further says—"When viewed with a high power there is no special texture; nothing but a finely granular mass appears, which is merely rather

darker and more obscure where the naked eye detects the opaque lines. No definite streak bounds the light and clear spaces; there is no evidence of a true membrane discoverable by the microscope within the hyaloid membrane; as far as we can see, the light and dark layers have the same amorphous structure" (p. 99). He also repeated Brücke's observations on the effects of diacetate of lead, but although he confirmed his description of the directions of the white lines that appear in the vitreous after the action of lead, he could find no evidence of any membranes: the white lines appeared merely to be due to a precipitate. In the vitreous humour of the bird, after the action of chromic acid solution, he found no concentric lamellæ, but "a very evident arrangement of opaque fibres, extending chiefly from the summit of the pecten through the vitreous towards the ora serrata, while others stretched from the ciliary body to the side of the lens" (p. 106). On hardening the vitreous humour of fishes' eyes in chromic acid, he found a distinct lamination in the vitreous, the laminæ passed from the region of the ora serrata to the side and back of the lens. Some of the anterior layers were derived at successive distances from the suspensory ligament of the lens. Although Bowman failed to find sufficient evidence of the existence of any but the hyaloid membrane in the vitreous, the result of the action of chromic acid nevertheless led him to say—"there remains good reason for supposing that there do exist certain layers in the vitreous capable of being rendered visible by art," and that "in the human eye the uniformity of the layers disclosed in the neighbourhood of the lens could hardly have been produced by simple immersion in chromic acid, independently of a pre-existing structure."

Kölliker (1860, *Op.* 4, p. 571) states that nothing can be seen of membranes in the fresh vitreous. Schwalbe (1883, *Op.* 5, p. 137, and 1884, *Op.* 6, p. 524), writing so recently as this year expresses the same opinion. Iwanoff (*Op.* 1, p. 349,) also denies their existence. On the other hand, Hans Virchow (1882, *Op.* 7) finds that the *fresh* vitreous mainly consists of extremely delicate membranes with an intervening albuminous fluid; there are also cells in small numbers. He has figured the cells of the vitreous as several observers have done, but has given no draw-

ing of the membranes, his description of which is likewise very inadequate. R. Virchow, Kölliker, and others have regarded the vitreous as consisting of mucous connective tissue, viz., branching connective tissue corpuscles forming a network with an intervening fluid containing mucin. Ciaccio (*Op.* 8, vol. vii. p. 376) is of opinion that delicate fibres and cells are its only solid constituents. Iwanoff (*Op.* 1, p. 345) and Schwalbe (*Op.* 5, p. 139, and *Op.* 6, p. 524) express a similar opinion. Iwanoff states that the cells of the vitreous are all amœboid, and are found only in its outer part. The fibres are wavy fasciculi bearing some resemblance to the fibres of connective tissue, and are found only in the peripheral part of the vitreous. Most are found anteriorly; in the posterior part there are only a few scattered fine fibrils; there are also a considerable number of fibres like elastic fibres commencing at the equator of the eye in the form of extremely fine looped fibres, first seen in large numbers at the ora serrata, where they form the commencement of the zonule of Zinn.

My observations on the vitreous, made on the eyes of the ox, sheep, rabbit, cat, rat, and cod, have led me to the belief that the fully developed vitreous is certainly an organised structure, altogether differing from mucous connective tissue. Its solid part consists of thin membranes, cells, and fibres, and I propose to give an account of the appearance and arrangement of these. I have not investigated the chemical nature of the fluid between the membranes, but this has been done by Lohmeyer, quoted by Schwalbe (*Op.* 5, p. 137 and *Op.* 6, p. 523) and Hans Virchow (*Op.* 7, p. 10), who finds that in ruminants and carnivora the fluid contains salts, extractives, and albumin, but no mucin. Schwalbe, however, finds a trace of mucin in the sheep, and also gives the composition of the fluid in the human vitreous and in that of the fish as differing from the fluid in the vitreous of the ox and dog, in containing mucin (*Op.* 6, p. 523).

Cells of the Vitreous Humour.—In the vitreous of the adult, the cells are, as stated by most authors, found mostly near the surface. They present two different types. (1) *Amœboid cells* of various shapes and sizes: oval, circular, flask-shaped, or quite irregular, the protoplasm being protruded as buds; these have

large nuclei, and a varying amount of coarsely granular protoplasm. Some cells contain two or three nuclei, but those internal to the limiting hyaloid membrane have generally a single nucleus. In some cases no protoplasm is visible, the nuclei being large and distinct. Lieberkühn and Schwalbe suppose these cells to be leucocytes derived from the retinal vessels in the region of the papilla optici, and also from the vessels of the ciliary body, and so account for their being found in greater numbers in the anterior and posterior regions of the vitreous. Pagenstecher (*Op.* 6, p. 555), observed them in the vitreous of the young rabbit on a hot stage under the microscope, and followed the different changes in form that they undergo. These cells are seen to lie on the inner surface of the limiting hyaloid membrane, as also on the inner surface of the other membranes in the cortex of the vitreous. Some of them may appear under the microscope to be folded round creases of the membranes, and they have then an appearance so like clasping cells, as to have led to the folds being mistaken, by some, for fibres developed from the cells. The character of the amoeboid cells is well seen in Plate I. fig. 1. (2) Besides the above, there are large and small *branching cells* with distinct nuclei; these also vary greatly in shape, and may be uni-, bi-, or multipolar. The processes are clear, and may be straight, curved, or twisted in various directions, and with straight or irregular outlines, the irregularity being due to a beading or varicosity along the course of the processes, which sometimes end in a distinctly beaded manner. I have seen some of these branching cells arranged so as to come in relation to a network, both in the adult and young animal. This network has been chiefly observed in the equator of the eye, in which region some of the fibres which run towards the zonule appear to lose themselves in the network. I have also seen bright elastic-looking fibres arising apparently as processes of cells in the region of the zonule, and adding themselves to the fibres of that ligamentous membrane. The character of the branching cells is shown in Plate I. figs. 2 and 3. Fig. 4 shows what at first appeared to be a network of branching cells in the region of the zonule, the fibres of the network corresponding in some of their microscopic characters with the elastic-looking fibres of the zonule, some of

which fibres can be traced to the network; the nature of this network will be considered later.

Vacuolated cells have been described by Iwanoff (*Op.* 1, p. 352) as a distinct type. It seems, however, unnecessary to classify them separately, inasmuch as they are merely derivatives of the first two types. Schwalbe (*Op.* 6, p. 536) attributes the formation of the vacuoles to inhibition, in consequence of their being found in adult life, when the vitreous is rich in water, and not generally in the embryo, where the vitreous is more consistent. Each cell may present one or more vacuoles, which at times attain a large size, quite displacing the nucleus, or they may be found in the processes of the branched cells where they give rise to dilatations. Schwalbe (*Op. cit.*) is of opinion that all the cells above described have a common origin, viz., are derived from white blood corpuscles which have undergone changes in configuration, in some cases to a marvellous extent. In support of this view he describes an experiment in which he placed, at different periods, the human vitreous and also that of the sheep and pig in the dorsal lymphatic sac of the frog, at the same time injecting a fluid containing fine coloured granules in suspension into the lymph spaces of the frog. The pigment granules were taken up by the lymph cells, and so carried eventually into the vitreous enclosed in the lymph sac. On examining portions of the vitreous removed after eighteen hours from the sac, he found that the lymph corpuscles which had emigrated into the vitreous had assumed various shapes, which corresponded in a marked manner to the different forms presented by the cells of the vitreous body. I am not at all prepared to admit that all the branching cells are mere modifications of lymph corpuscles; some may fall into that category, *e.g.*, the cells with beaded or irregular processes as shown in Plate I. fig. 3, but there are other branching cells with bright sharply-defined processes, some of which are of great length, which seem to be of a different nature, and others again fusiform or irregular in shape which I have frequently seen in relation to a network of clear fibres, which, though represented in Plate I. fig. 4 as forming the network by union of their processes, may be of the nature of connective tissue corpuscles in close relation to the fibres. These will again be

considered in alluding to the fibres of the vitreous. In passing, I might say there are other cells among the zonular fibres which are distinctly clasping cells giving origin to the fibres. These are seen in Plate II. fig. 10.

Membranes.—The membranes of the vitreous constitute by far the most important structural constituents of the tissue. They can be seen on examining with the microscope portions of the fresh or hardened vitreous snipped off with a pair of scissors from *any part* of the organ, or by making complete antero-posterior or vertical sections through the vitreous shrivelled by placing it in a strong solution of gum or glycerine. The most external membrane, or so-called hyaloid membrane, can however be separated by the action of hardening agents, as Kleinenberg's picric acid solution,¹ or ammonium chromate solution (5 per cent.); it forms a sort of capsule for the vitreous. Each membrane presents a homogeneous appearance when it is spread out, but the surface may be readily thrown into innumerable folds and crimples, the latter giving in some places the impression of fibres, more especially where a cell is folded round it. The resemblance is so striking, that I had much hesitation at first in pronouncing as to their nature, but, judging from the optical characters of the crimples, and their similar appearance in other parts where no cells can be made out, as is the case near the centre of the organ in the adult, I consider them to be folds or creases and not fibres. The general character of the membranes, folds, and crimples is well brought out by staining agents, *e.g.*, carmine (Plate I. fig. 5), logwood, chloride of gold (Plate I. fig. 6), &c., when the general surface presents a uniform tint, with darker straight, curved, or twisted lines, or bands corresponding to the folding or crimping. The crimples or creases assume very peculiar shapes in some cases, which may present here and there a corkscrew-like arrangement. The external membrane, or so-called hyaloid membrane has been considered as a special structure; according to my observations, however, it does not differ from the internal membranes except in being thicker, and therefore I think it is unnecessary, and indeed misleading, to distinguish this membrane by the special name of hyaloid

¹ To 100 c.c. saturated solution of picric acid add 2 c.c. sulphuric acid; filter, and add 300 c.c. distilled water.

membrane, inasmuch as all the membranes are hyaloid. It may, however, with propriety, be termed the limiting hyaloid membrane (*membrana limitans hyaloidea*) as Henle has proposed. Iwanoff (*Op.* 1, p. 346) regards it as identical with the inner limiting membrane of the retina, but in this I differ from him entirely. Plate I. figs. 5 and 6 show the characters of the external and of one of the internal membranes respectively. These clear, homogeneous, hyaloid membranes are so arranged as to give rise to a concentric lamination, the laminae extending to the canal of Stilling, which courses through the centre of the vitreous, from the posterior pole of the organ, where there is a distinct depression opposite the papilla optici of the retina, marking its origin, to near the posterior surface of the crystalline lens, where it ends in a blind extremity. The arrangement of the membranes in the region of the canal of Stilling can be explained by the membranes being invaginated by the entrance of the hyaloid artery which occupies the canal in the foetus. With regard to the portion of vitreous immediately posterior to the lens, it is likewise composed of concentric membranes continuous with those at the sides. The limiting hyaloid membrane is continued forwards internal to the zonule of Zinn, becoming more delicate as it passes behind the lens, and, similarly, the other membranes are continued forwards within it. The presence of these membranes behind the lens may be demonstrated by examining even fresh portions of the vitreous after removal of the lens, or of the great mass of the vitreous from behind.

Plate II. fig. 7 shows a clear membrane in relation to the capsule of the lens; a part of the membrane is torn and folded over, exposing the capsule behind it. Schwalbe denies this concentric arrangement of membranes, on the ground that if the vitreous be pricked externally, all the fluid from its interior passes off, leaving a shrivelled mass, which, he argues, would not be the case if the fluid was enclosed in *different compartments* constituted by membranous partitions. He, however, does not take into consideration the fact that in the foetus the vitreous is full of vessels which communicate freely in all parts of the organ; in the adult no vessels are found, but there is no reason why the fluids in the different compartments of the vitreous

should not communicate by means of tracts left in the adult by the foetal vessels, just as the canal of Stilling represents in the adult the situation of the hyaloid artery of the foetus. Klein is of opinion that the canal of Stilling has nothing to do with the course of the hyaloid artery; I have, however, seen in the eye of the ox a conical projection from the centre of the papilla optici exactly opposite the depressed commencement of the canal, and in fact fitting into the depression. This projection can be injected through the distal end of the central artery of the retina, and is very probably the remains of the hyaloid artery.

The Canal of Stilling, or central canal of the vitreous, can be easily demonstrated by the injection of a coloured fluid through the distal end of the central artery of the retina, after section of the optic nerve. On injecting a solution of soluble Prussian blue, the course of the canal could be readily distinguished, but there were no indications of any smaller canals or slits communicating with it as Stilling describes (*Op.* 6, p. 526). The walls of this canal appear to be smooth, and composed of clear membranes of the same nature as above described.

The Zonule of Zinn, or suspensory ligament of the lens, has been the subject of much dispute among authors. Schwalbe, Klein, and others consider it to be a modified continuation of the hyaloid membrane; according to Henle, it is the middle division of the membrana limitans interna of the retina, while in the opinion of Iwanoff it arises in the substance of the vitreous in the form of delicate fibrils which arise within the vitreous, in great part behind the ora serrata, pass up towards the ora, become applied to the membrana limitans interna of the retina (thus accounting for the close connection between the retina and vitreous in this region), and finally pierce the vitreous at the ora to form the zonule. Some fibres also arise from the vitreous in front of the plane of the ora serrata, and, passing out, are added to the fibres of the zonule (*Op.* 1, p. 354). My observations are quite in accordance with those of Iwanoff in regard to the origin of the fibres of the zonule of Zinn. I cannot believe that the zonule is merely a modification of the hyaloid membrane, inasmuch as it is composed of fibres running in so many different directions. Plate II. figs. 8 and 9 show

two and three layers of fibres respectively running in different directions, and I have seen other layers of fibres pursuing a still more varied course, which for the sake of simplicity have been omitted in fig. 9. It is in some cases easy to see the fibres curving at their extremities and dipping into the vitreous either individually or in strands, in the latter case giving rise to distinct ridges and furrows on the surface of the preparation which mark the lines of curving and penetration respectively. It is quite true that the outer membrane presents a distinctly fibrillated appearance at and near the zonule; this, however, is easily explained by the fact that, as Iwanoff has described, the fibres run along the inner surface of this membrane for some distance near the region of the ora serrata before piercing it. As the membrane is pierced along several lines between the ora serrata and the margin of the crystalline lens, it is evident the fibrous thickening of the membrane is carried beyond the ora towards the lens. The latter fibres, on piercing the membrane, add themselves to those which have already passed out, so that the zonule is constantly receiving additions in its course to the lens. The outer membrane of the vitreous, as before stated, passes inside the zonule to cover the surface of the vitreous behind the lens, and in so doing leaves a space between it and the zonule, which during the life of the animal is filled with a fluid; it is, in fact, the lymph space or canal of Petit, bounded anteriorly by the zonule of Zinn, and posteriorly by the vitreous covered by its proper membrane.

The anterior boundary, or zonule of Zinn, though forming a continuous membrane, does not completely shut out the canal of Petit from the posterior chamber of the eye, as there are some apertures of communication between these two lymph spaces, which are probably situated near the lens margin, seeing that a solution of soluble Prussian blue is found to penetrate the zonule near the margin of the lens when injected into the anterior chamber of the eye.

The nature of the fibres of the zonule of Zinn has been much disputed, and in fact is yet far from determined. They present a stiff highly refractile appearance, are seen to branch and stain with picric acid and to some extent with magenta and eosine. Some of them may become swollen by absorption of water,

still however retaining their peculiar characters. Besides these there are distinct white fibres in the zonule, as some of them are seen in process of development in young animals. Plate II. fig. 10 shows two of these fibres as observed in the young rabbit. On following the zonular fibres forwards towards the lens, they split up in the form of a brush to be attached to the anterior and posterior parts of the capsule of the lens. Those attached to the anterior part of the capsule can be traced for some distance along its surface, serving to strengthen it and at the same time making its attachment more secure. This accounts for the anterior part of the capsule of the lens being thicker than the posterior. Tracing the fibres of the zonule back to their origin, they are seen to be formed by the union of delicate fibrils which can be followed into the vitreous. Here the elastic-looking fibrils form an open network, which very closely resembles a network of elastic fibres, and here and there cells are seen closely applied to the fibres. This is well seen in Plate II. fig. 9, where a fibre can be distinctly traced from the elastic-looking network, and is then seen to divide and mingle with the fibres of the zonule, which it exactly resembles. In Plate I. fig. 4, which was previously alluded to when describing the cells, we have a similar network, in the young rabbit, in the region of the zonule. Here the fibres are represented as though they were processes of cells, and I am obliged to admit such was my opinion when the figure was drawn. I am now of opinion, however, that the cells are here, as in fig. 9, closely applied to the fibres. Two clear fibres are seen passing from this network, and are not recognisable from the zonular fibres.

Fibres of the Vitreous—Besides the elastic-looking fibres found in the equator of the eye and in the region of the ora, there are others of the same nature in the substance of the vitreous behind the lens, where they can be seen to form a network as well. In the posterior pole and in the centre of the vitreous, however, the fibres are few in number, and scattered here and there in the preparations; they present nevertheless the same clear appearance and sharp borders as the fibres above described. Lieberkühn describes fibres which are the remains of the embryonal vessels in the vitreous. I have been unable to distinguish these in my preparations, though I have seen certain

swollen fibres in the anterior pole of the vitreous which look much like white fibres; these I am inclined to believe belong to the region of the zonule as white fibres have been seen to develop there (see Plate II. fig. 10). From the above description it is evident that most of the fibres just described bear a close resemblance to the 'fibres of the zonule of Zinn. This is especially true of the elastic-looking networks with which some of the zonular fibres have been shown to be continuous.

The importance of the anatomical fact that the zonule of Zinn arises in the substance of the vitreous, as above described, will be evident, if we consider for a moment the relations of the zonule, and its bearings on the mechanism of accommodation. The anterior part of the choroid, at, and anterior to, the ora serrata, and especially the ciliary processes are adherent to the zonula. Here also the retina is more closely related to the vitreous; therefore, when the ciliary muscle is put in action, it draws not only the ciliary processes and choroid forwards, but also to some extent the zonule of Zinn. Were the zonule of Zinn continuous with the inner limiting membrane of the retina or with the so-called hyaloid membrane, positive accommodation would be attended by a drawing forward of the retina against the vitreous, on the one hand, or by a bulging posteriorly of the vitreous on the other; in either case the retina would be rendered anæmic by pressure, and consequently less sensitive to the image focussed on it. As accommodation occurs so very frequently, a constant emptying of the retinal vessels would lead to injury of its delicate structure and interference with sight. Such, however, is fortunately not the case, for the zonule arising in the vitreous and being connected with a network peripherally, at, and anterior to the equator of the eye, every pull on it is distributed to the fibres in the anterior part of the vitreous, and hence the force being so spent, no bulging of the vitreous posteriorly can occur, as would be the case if the zonule were a modification of the outermost or so-called hyaloid membrane. Before leaving the consideration of the fibres of the vitreous I have still to allude to a delicate network of fibrils, the description of which has been deferred on account of its perplexing nature. It can be demonstrated in all parts of the vitreous, but is especially well marked in the cortical portion.

I first noticed this network in the vitreous of the young rabbit, injected during the life of the animal (while fully under the influence of an anæsthetic) with a $\frac{1}{2}$ per cent. solution of gold chloride, the eye being subsequently exposed to light for about twenty-four hours. On examining portions of the vitreous so treated, the membranes were found to be stained with the gold, which also stained a delicate network of fibres lying on the surface of the membranes in some parts of the preparation. The network as observed is represented in Plate II. fig. 11. Not being able at first to determine the nature of the network, I repeated the experiment on the eye of the young rabbit soon after death, and likewise on the fresh vitreous of the ox, with the same result. The network stood out prominently, and appeared to consist of large and small bundles of fibrils forming fibres, from which the fibrils were every here and there given off as branches, passed in various directions and united with one another to form a very delicate network. This at first sight seemed to be produced by a precipitation of fine coloured granules on the surface of delicate fibres. On careful focussing, each fibril was seen to consist of a row of bright globules enclosed in a *distinct sheath*, while in some places there were varicosities in the course of the fibrils. I was at first under the impression that we had here to deal with a network of delicate elastic fibres, and hence considered it as analagous to the network above described as being in relation to the zonule. On investigating the subject still further, I observed that it was possible to demonstrate the network in the fresh vitreous of animals, by tinting with carmine, or by the ordinary silvering process for tissues. In all cases I obtained the same appearances, and was much struck by the marked resemblance of the network to the arrangement of nerve fibrils as seen in the cornea, mesentery, &c. The appearance of the network and its close correspondence to that of delicate nerve fibrils is seen in Plate II. fig. 12. The larger bundles of fibrils, with indications of fibrillation, the delicate fibrils themselves beaded in some places and at times very regularly so, and finally their staining with gold, carmine, and nitrate of silver, were all extremely suggestive of their nervous nature. I advance this view, however, with some reserve, considering that the presence of nerves in the vitreous

has never even been hinted at by previous observers. The vitreous, however, being a fully organised tissue, it seems to me not more remarkable that it should contain nerve fibrils than that they should be found in the substance of the cornea, and in other forms of connective tissue.

In conclusion, I have to acknowledge my indebtedness to Professor Rutherford for his kindness in suggesting the above to me as a subject for research, for the use of his laboratory, and for the encouragement and assistance he has been ever ready to render me in my investigation of this difficult and often perplexing subject. I have finally to thank him for his supervision of this paper, to which I have much pleasure in giving publicity, hoping that thereby the subject will once more engage the attention of eminent observers.

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EXPLANATION OF PLATES I AND II.

Fig. 1. shows large amœboid cells taken from the posterior pole of the vitreous of the ox, internal to the limiting hyaloid membrane. Stained with picro-carmin. The nuclei are very distinct, and usually contain nucleoli; some cells are vacuolated. *a*, vacuole; *b*, cell breaking down. $\times 700$.

Fig. 2. Branching cells as seen in the vitreous of the ox near the equator of the eye. Two are vacuolated, *a*. The processes are of various shapes, some straight and clear as at *b*. $\times 500$.

Fig. 3. Branching cells from near the equator of the eye with nuclei and vacuoles. Processes with irregular outlines due to beading along its course, some end in a beaded manner. *a*, vacuole; *b*, beaded extremity. $\times 700$.

Fig. 4. Network of clear fibres from anterior portion of vitreous of young rabbit. Cells are seen in close relation to the network as at *a*; *b*, a fibre following a somewhat curved course; *c, c*, two straight clear fibres resembling the zonular fibres. $\times 700$.

Fig. 5. Portion of limiting hyaloid membrane of ox much crimped and creased, stained with carmine. $\times 375$.

Fig. 6. Portion of internal membrane of ox folded and creased. *a*, a fold; *b*, a crease; *c*, homogeneous surface of membrane. $\times 375$.

Fig. 7. Portion of membrane behind lens capsule; also a network on darkly stained portion, taken from eye of young rabbit injected with gold chloride. *a*, capsule of lens; *b*, clear membrane; *c*, darkly stained membrane with a network of fibrils; *b'*, portion of clear membrane torn off and folded over, exposing lens capsule. $\times 375$.

Fig. 8. Portion of zonule of Zinn with pigment cells of two ciliary processes lying on it. *a*, pigment cells of ciliary processes; *b*, hexagonal cells of pars ciliaris retinae; *c*, ridge of zonular fibres between adjacent processes; *d*, superficial plane of clear elastic-looking fibres; *e*, deeper plane of fibres running nearly at right angles to *d*. $\times 375$.

Fig. 9. Portion of zonule of Zinn of cod, showing three layers of fibres *a, b, c*; on *c* is seen a network of elastic-looking fibres *d*, from which a fibre passes up, divides and becomes lost among the other fibres of the layer; *e* and *f* two cells in close relation to the fibre which runs upwards; *g* and *h* are the divisions of the fibre. $\times 375$.

Fig. 10. Two developing fibres of white fibrous tissue from the region of the zonule of Zinn.

Fig. 11. Network of fibrils as seen in the eye of the rabbit injected with gold, it is left uncoloured in drawing. *a* and *b*, membranes darkly and faintly stained; *c*, network of fibrils. $\times 375$.

Fig. 12. Network of fibrils lying on the surface of a membrane, stained with gold chloride; there are large and small bundles, and also delicate fibrils. The appearance is much like nerve fibrils, which, however, are irregularly beaded, except here and there, where varicosities are clearly seen. Two fibres project beyond the membrane. *a*, membrane; *b*, fibre; *c*, fibril; *d*, fibril with distinct varicosities $\times 700$.

ON THE COMPARATIVE VARIABILITY OF BONES
AND MUSCLES, WITH REMARKS ON UNITY OF
TYPE IN VARIATIONS OF THE ORIGIN AND
INSERTION OF CERTAIN MUSCLES IN SPECIES
UNCONNECTED BY UNITY OF DESCENT.¹ By
G. E. DOBSON, M.A., F.R.S.

So many papers have been written on the variability of muscles that several biologists, who have not specially studied the subject, have formed the opinion that nothing in the structure of an animal is half as variable as a muscle, and that, consequently, little value attaches to any deductions one may be led to make from the closest study of these parts. They forget, however, that, in the first place, these published notes have been almost wholly confined to the muscles of man, the very type of a domestic animal, and therefore, as Darwin points out, a most unsuitable subject for studying fixity of type in; and secondly, that the few variations recorded represent the exceptions to the rule in thousands of normally formed bodies. It is on this very principle that exceptions are few, that writers of works on human anatomy have been able to lay down with exactitude, in few words, the limits of the origins and insertions of the muscles, and the student rarely, indeed, finds that his book fails to describe sufficiently accurate the relations of the muscular structures he is examining.

From study of the muscular structure of mammals killed in the feral state, I have formed the opinion that muscular variability in the same species is a matter of extreme rarity—so rare as to form a very unimportant factor, indeed, in affecting general deductions which may be based on the study of few examples of given species.

An anatomist has remarked that it appears unquestionable that the arrangement of the muscular system is intimately connected with and altogether subordinate to that of the bony

¹ Read before the Biological Section of the British Association for the Advancement of Science, at the Montreal Meeting, 2nd September 1884.

framework.¹ This, which at first sight appears to be an axiomatic statement, although undoubtedly true to a great extent, yet is not absolutely so, for I shall presently show that, not only many most important changes in the form and arrangement of the muscles have taken place quite independent of the osseous structures they are attached to, but also many muscles are much more permanent than the bones of the limbs to which they belong, and by their permanence afford important indications of the extensive changes that have befallen the skeleton.

Of all the different parts of the osseous framework of the animal body, none are so liable to modification as the bones of the extremities; and here we may therefore study with best effect the subject under consideration.

To pass at once to an instance of extreme modification of the bones of the fore-limbs, we have only to consider their condition in the bats, where the shaft of the ulna is reduced to a mere thread-like bony spicule anchylosed with the radius, whilst the head scarcely enters into the formation of the elbow-joint. Nevertheless, all the usual muscles, with the exception of the *pronator quadratus*, are present, and, as Professor Humphry has shown in *Pteropus*, the only differences from the dorsal muscles of the human fore-arm and hand are to be found in the insertion of the supinator and in the extensors of the pollex. Even in the horse, where the ulna is represented only by the olecranon and upper part of the shaft, and the digits are reduced to one, most of the forearm muscles of the five-toed mammals are represented, the *extensor minimi digiti* even surviving, although both its insertion and special function have long been completely altered.

In the hind-limb, however, the relative modification of bones and muscles are even better exemplified, for there the changes displayed throughout the mammalian series are more diversified and intense.

The hind-limb of most bats affords an instance of intense modification not less remarkable than that of the fore-arm, for (except in the sub-family *Molossinæ*) the fibula is either very slender, or cartilaginous and ligamentous in its upper third, or

¹ George, "Monographie du genre *Damen*," *Ann. des Sci. Nat.* vi^{me} Sér., t. 1^{re}, p. 123.

reduced to a small bony process above the heel, or altogether absent, as in *Nycteris*.¹ Nevertheless, the *flexor digitorum fibularis* (*flexor hallucis longus*), which in all other mammals arises almost altogether from the fibula, is present, having shifted its origin inwards to the outer side of the tibia, as in many bats, or upwards to the outer condyle of the femur,² as in *Nycteris* and some other species, which in this respect resemble birds. Professor Humphry has pointed out that, although the upper part of the fibula is altogether absent in *Pteropus*, the *peroneus longus* is present, having simply shifted its origin to the tibia.³

The independent character of the changes which affect bones and muscles, is nowhere better illustrated than when we compare the several modifications of the long flexor muscles of the feet of mammals and the concomitant condition of the bones of the legs and feet to which they are attached.

In a paper published in a preceding volume of this *Journal*⁴ I demonstrated the fact that two types of arrangement of these muscles—the *flexor digitorum fibularis* (*flexor hallucis longus*) and *flexor digitorum tibialis* (*flexor digitorum longus*)—were recognisable, namely, a united condition of their tendons in the sole of the foot, present in most placental mammals, and a dis-united, caused by separation of the tendon of the *flexor digitorum tibialis*, as seen in certain families of placental mammals, and in nearly all the implantal. Now it is worthy of special notice that the united or disunited condition of the tendons of these flexors

¹ In a specimen of *Nycteris hispida* I find a small cartilaginous process attached by ligament to the outer side of the head of the tibia, giving origin to some fibres of the *flexor fibularis*. This may be a rudiment of the head of the fibula.

² The muscular fibres are therefore continued from the femur across the knee-joint, as in the undifferentiated condition still represented by the *ambiens* muscle of crocodiles and many birds. See Gadow, "Observations in Comparative Myology," *Journ. Anat. Phys.*, vol. xvi. pp. 502-3.

³ The peculiar course of the *rectus abdominis et sternalis* muscle in the golden moles (*Chrysochloris*), affords an interesting example of the capability of muscles to accommodate themselves to altered conditions of the skeleton. In these animals, the usual course of this muscle being interfered with by alterations in the form of the thorax, it has assumed a position altogether different from that of any other known mammal, lying superficial to, instead of under cover of, the pectoral muscles. See the writer's notes on this condition of the muscle, at pp. 84-85, vol. xvii. of this *Journal*.

⁴ Vol. xvii. pp. 142-179, plates iv.-vi.

appears to have no relation whatever to the united or disunited state of the leg-bones. Thus, although the fibula is well developed in all the implantal mammals, in the sciuromorphic rodents, and in the American species of Edentata, the *flexor digitorum tibialis* is nearly always separate, or the muscle is altogether absent; while, on the other hand, in all Chiroptera and Ungulata, in which this bone is generally rudimentary or fused with the tibia, the tendon of that muscle is united in the foot with that of the *flexor digitorum fibularis*, as it is in the Carnivora and Primates, where both bones are well developed.

Just as in the marsupial, *Hypsiprymnus gaimardi*, where the animal walks on a single toe and the long flexor muscles are reduced to one¹ (the fibular flexor), so, in the one-toed horse, one, who was acquainted with the anatomy of the former species only, would expect to find similarly a single flexor; but his expectations would not be realised, for the horse has both flexors, with well-developed tendons united in the foot, as in the greater number of five-toed mammals, a sure indication of his five-toed ancestry.²

The migration of the tibial flexor (which normally arises, as we find it in *Centetes*, from the head of the fibula, the interosseous membrane, and the adjacent margin of the upper part of the shaft of the tibia) from the fibular to the tibial side of the popliteus muscle generally occurs (in placental mammals) as a prelude to the separation of its tendon from that of the fibular flexor, and is evidently due, not to changes in the bones of the

¹ *Journ. Anat. Phys., loc. cit.*, plate v. fig. 9.

² In my paper already referred to I have shown how, in *Centetes ecoudatus* (which in many respects presents a better example of an undifferentiated Eutherian than even *Gymnura rafflesii*), the evidently original mode of distribution of the tendons of these muscles in the ancestral forms from which existing mammals have sprung may still be traced; for in this species their connections, as they overlies one another, are not so close as to prevent their exact discrimination; and it may at once be seen (*Journ. Anat. Phys., loc. cit.*, plate iv. fig. 1) that, while the tendons of the *flexor digitorum fibularis* supply the three middle toes, those of the *flexor digitorum tibialis* are distributed to the outer and inner toes respectively. All connected conditions of these tendons in other mammals are evidently but modifications of such an original arrangement, and the presence of the tendon of the tibial flexor in the foot of any mammal, however modified, indubitably points to a pre-existing five-toed state; so that, in the case of the horse, if no other evidence were attainable of his five-toed ancestors, the presence of the two deep flexors we find in his pes would sufficiently indicate them.

limbs (for we find it in the horse on the fibular side), but to increase in the size of the body of the fibular flexor, which occupies its attachment, and gradually forces it towards the internal margin of the tibia.

Intermediate conditions are beautifully shown in the marsupial flying squirrel (*Belideus flaviventer*), in *Solenodon cubanus*, in the Pyrenean water-mole (*Myogale pyrenaica*), in the American jumping mouse (*Zapus hudsonius*), in the great rodent mole (*Bathyergus maritimus*), and in the common hedgehog. In *Belideus* (*Journ. Anat. Phys., loc. cit.*, plate v. fig. 8) the tibial flexor has partially migrated to the tibial side of the popliteus muscle, retaining still its connection by a few fibres with the fibula, while its tendon has separated in the foot from that of the fibular flexor, and become attached to the base of the first metatarsal bone, these changes, it may be noticed, having taken place quite independent of any alteration in the fibula. In *Zapus* (*loc. cit.*, plate vi. figs. 4, 4a) the greatly-increased size of the fibular flexor, evidently consequent on the weight when leaping being thrown on the three middle toes, has forced the tibial flexor away from its fibular and interosseous attachment altogether, so that it occupies the shaft of the tibia immediately below the insertion of the popliteus, while its tendon has thrown out a second slip, apparently preparatory to separation from the fibular flexor. In *Solenodon* (*loc. cit.*, plate iv. fig. 2), where the three middle toes are so much larger than the others, probably for digging, we find a similar but more advanced stage; for the fibular flexor (which, as shown in *Centetes*, specially supplies these toes) has so increased in size and attachment as to occupy not only the whole space on the fibular side of the popliteus, but also part of the shaft of the tibia below the insertion of that muscle, so that the tibial flexor has been obliged to seek a new attachment on the tibial side of the popliteus. In the Pyrenean water-mole (*loc. cit.*, plate iv. fig. 5), where the digits are so much lengthened, this enlargement of the body of the fibular flexor has attained the greatest possible extent; for it occupies the whole posterior surface of the shafts of the fibula and tibia, and the greater part of their heads, while the tibial flexor is reduced to the state of a mere rudimentary muscle, attached on the tibial side of the popliteus to the upper

margin of the head of the tibia. In the true moles (*Talpa*) the relations of these muscles are similar, but the tibial flexor is larger. The great rodent mole (*Bathyergus maritimus*) presents an instance of similar changes in the muscular structures, induced by similar habits in an animal otherwise widely separated from the true moles. Here the large fibular flexor, as in *Myogale*, has forced the tibial flexor inwards, so that the latter is attached to the head of the tibia internal to the attachment of the popliteus; and its tendon having separated in the foot from that of the fibular flexor, is attached, precisely as in the true insectivorous moles, to the tibial margin of the basal phalanx of the hallux, developing, as it crosses the ento-cuneiform articulation, a broad sesamoid ossicle.

A review of these facts suggests two interesting questions:—

1. What were the causes which led to final separation of the tendon of the *flexor digitorum tibialis* from that of the *flexor digitorum fibularis*.

2. How happens it that, in certain widely separated species, in no way connected by descent from a common ancestor having similar peculiarities, separation of this tendon from that of the fibular flexor and attachment to a different part of the foot has occurred in a perfectly similar manner.

I have already partly indicated what I believe to be the solution of the first question, namely, that, seeing that the three middle toes are supplied by the fibular flexor, whatever cause might lead to greater work being thrown on these digits would necessarily lead also to increased size in the body of the muscle, and, consequently, to a more extended origin for its fibres; and that this increased origin, if carried sufficiently far, must occupy the whole fibular side of the tibia, and so force the less used tibial flexor to the internal side of the bone. In such a position it is evident (*loc. cit.*, plate iv. fig. 2) that its tendon, being united at a considerable angle with the side of the tendon of the fibular flexor, has a constant tendency to separate from the side of that tendon. If now, previous to separation, it has, by the formation of a second tendon, attached itself to any other part of the pes, as in *Solenodon cubanus* (*loc. cit.*, plate iv. fig. 2), such connection will be maintained or, perhaps, extended after separation, as we find in some species, such as in *Erinaceus europæus* (*loc. cit.*, plate iv.

fig. 3), *Crocidura cærulescens* (*loc. cit.*, fig. 4), *Myogale pyrenaica* (*loc. cit.*, fig. 5), *Bathyergus maritimus* (*loc. cit.*, plate iv. fig. 6), and in many species of Rodentia, Edentata, and Marsupialia, where it is connected with the first metatarsal bone, or with the first hallucal phalanx. If, on the other hand, it has not formed such connections, it may attach itself, after separation from the fibular flexor tendon, to the superficial fascia and integument of the sole of the foot, as we find it in some species of *Erinaceus*, *Myoxus*, &c., or it may disappear altogether, as we notice in others.

Now there are two conditions, namely, fossorial and climbing actions, which tend to throw most work on the three middle toes, and so lead to the development of the fibular flexor, and separation from it of the tibial tendon, as we find it in all the species of true moles (*Talpidae*), hedgehogs (*Erinaceidae*), and shrews (*Soricidae*),—which are all so closely allied that they may well have been derived from a common ancestor,—also in most of the fossorial Rodentia and Edentata, and in Echidna and Ornithorhynchus, the fossorial habits of which are so well known; also among arboreal mammals¹ (or those descended from ancestors having arboreal habits), as in the squirrels and dormice, the arboreal Edentata (*Brachypodidae*, *Myrmecophagidae*) and their descendants, and in nearly all the marsupials.

It is especially interesting that the arrangement of the long flexors in the pes of the marsupials has led me to form an opinion similar to that deduced by Professor Huxley² from the prehensile character of the pes, namely, “that the primitive forms whence the existing Marsupialia have been derived were arboreal animals.”³

¹ Two different modifications of the pes for climbing are observable, one in which the three middle toes and their claws are especially elongated, and climbing is effected by the claws, as in the squirrels and other arboreal non-quadrumanous animals, the other, in which the four outer toes are nearly equally elongated, have flat nails, and the hallux is more or less opposable, climbing being effected by the grasping action of the digits, as in the Quadrupedia and Lemuroidea; in the former we find, as by my theory we should expect, the tibial flexor separated, and, in the latter, still united with the fibular flexor.

² “On the application of the laws of evolution to the arrangement of the Vertebrata, and more particularly of the Mammalia,” by T. H. Huxley, F.R.S., *Proc. Zool. Soc.*, 1880, pp. 655, 656.

³ The Dasyuridae alone are probably an exception to this rule. In *Thylacinus* neither the form of the pes nor the arrangement of the long flexor muscles indicate descent from arboreal ancestors, and, although, in the arboreal species of the

Solution of the second question is attended with much greater difficulties. We see, as I have shown, how in two very different animals, such as the common mole, and the great rodent mole, which resemble one another only in living under ground, and in similarly using their hind feet, precisely similar modifications of the deep flexor muscles have been brought about. The similar separation of the muscles in the progenitors of both animals is easily understood, as above explained, but not so the peculiar mode of attachment of the separated tendon of the fibular flexor, so perfectly similar in both. Such unity of type unexplained by unity of descent seems capable of being understood only under the assumption that the special modification arrived at, is, in both cases, the best possible, and that it has been reached in both animals independently by natural selection.

family separation of the tendons of these muscles has taken place, yet it appears probable that they and *Thylacinus* are the descendants of some terrestrial form provided with five unmodified digits.

Beside the separation of the tibial flexor in the pes, there are other characters in the feet of all marsupials, except *Dasyuridae* and *Didelphidae*, which, whether the hallux be rudimentary, or, as in most species of *Macropodidae* and *Peramelidae*, absent altogether, affords absolute proof of its pre-existence and opposable condition in the ancestral forms from which all the species of these families were derived. I refer to the united and more or less rudimentary state of the second and third digits, the cause of which has long puzzled zoologists. How this has been brought about by the development of an opposable hallux in the pes of animals in which separation of the tibial flexor had previously taken place, I purpose demonstrating in a future communication.

CONGENITAL MALFORMATION OF THE TRACHEA
OF A HORSE. BY F. SMITH, *Veterinary Surgeon, 12th*
Royal Lancers.

MALFORMATIONS of the trachea of the horse are by no means common, and I can find no account on record of the peculiar condition which I am about to describe. An aged Australian horse was under my professional care for lameness. I noticed a strange appearance of the front of the neck over the trachea, the part being flattened, with a large depression in its centre running some distance down the neck. On examining this, I found the trachea large, flattened, and unyielding, with a space 3 inches wide in the centre, which could be traced from just below the larynx into the chest. The borders of this space were formed by the trachea, its edges being rounded and unyielding. The space was soft and compressible, and the finger could easily be pressed into the channel of the trachea. My first impression was that there was a rupture of the tracheal rings, for I need hardly say that normally there is no incomplete condition of the cartilaginous rings at the anterior part. Further examination showed that this could not be the case on account of the extent of the lesion. I could only infer that the posterior part of the trachea (that part nearest the vertebra, where the rings are normally incomplete, and their two sides connected together by muscular and fibrous tissue) was twisted round, so that the posterior part became anteriorly placed. The patient when trotted "roared" badly.

He was destroyed for incurable lameness, and I thus had an opportunity of examining the trachea.

The larynx was not distorted, but there was atrophy and fatty degeneration of the muscles on its left side. From below the larynx the trachea twisted round so that the posterior part became anteriorly placed. The rings were wide and flattened, towards the centre of the neck they were very rigid, and at the lower part they became angular, and had bony protuberances on them. All the rings ended by a flattened square edge on one

side, and on the other they were thick and abrupt as if cut with a knife. Connecting these two edges of the trachea was a thin, fibrous, shiny, tough membrane, which on the cut-like edge formed bands, but not so on the other; lower down the bands disappeared, but the connecting membrane was more tense. The width of this connecting membrane (and consequently the distance between the two edges of the trachea) was, superiorly, immediately behind the cricoid cartilage, 1 inch; centrally, opposite the third and fourth cervical vertebræ, 3 inches; and inferiorly, above the bronchi, 2 inches. It was this membrane I had felt during life, and resting on it was the œsophagus, which thus ran near the central line of the neck instead of down the left side. Just before the trachea broke up into the bronchi, a piece of narrow thin cartilage, 4 inches in length, was found lying in and attached to the connecting membrane of the edges of the trachea; it ended abruptly at the bronchi by overlapping three or four other large plates of cartilage which were coming from the bronchi. This condition was most singular. The circumference of the trachea was, superiorly, $8\frac{1}{2}$ inches; centrally, $9\frac{1}{2}$ inches; inferiorly, $9\frac{1}{2}$ inches; just in front of the bronchi, $7\frac{3}{8}$ inches. The number of rings in the trachea was fifty-six.

Transverse sections of the trachea were made at regular intervals throughout its length in order to show the calibre, and these proved most interesting. The first section, 4 or 5 inches below the larynx, showed that the tube was oval, the opening being 3 inches in its transverse diameter, and $\frac{7}{8}$ inches in its antero-posterior diameter; second section showed the lumen much narrower, the ring at one part being flat, the measurements were $2\frac{5}{8}$ inches in its transverse, and $\frac{3}{8}$ inch in its antero-posterior diameter; third section, this was very singular, here the space for the air to pass through was reduced to a most insignificant size, it was $2\frac{7}{8}$ inches in its transverse and $\frac{3}{8}$ inch in its antero-posterior diameter; fourth section showed the channel considerably enlarged, it was 3 inches in its transverse and $1\frac{1}{8}$ inch in its antero-posterior diameter; the fifth section was again larger, it was $2\frac{3}{8}$ inches in its transverse and $1\frac{3}{8}$ inch in antero-posterior diameter; in the sixth section the rings of the trachea were singular, and the passage was $2\frac{5}{8}$ inches in transverse and 1 inch in antero-posterior diameter.

26 CONGENITAL MALFORMATION OF TRACHEA OF A HORSE.

Distortions of the trachea of the horse have been known to occur from the abuse of the "bearing rein," but these are of a surgical rather than anatomical interest. The malformation I have described was congenital, and such a condition as the trachea being twisted and flattened is, I think, of sufficient interest to the anatomist to warrant me in placing the case on record.

ON THE NATURE OF LIGAMENTS. (PART II.) By
J. B. SUTTON, F.R.C.S., *Lecturer on Comparative Anatomy,*
Middlesex Hospital Medical School. (PLATE III.)

SECTION I.

IN a previous number of this *Journal*¹ I ventured to advance some views respecting certain ligaments of the human body. Since that essay was published abundant good material has come to hand enabling me to extend the investigation. In the present paper particular attention will first be devoted to the ligaments connected with the clavicle, scapula, and humerus, in order to show the relation they bear to muscles, and to strengthen the theory previously enunciated, that "many ligaments are the *tendons of muscles* which were originally in relation with the joint, but the parent muscle has either formed new attachments or become obsolete, whilst the tendon remains as a passive element in the articulation," the above statement being really the text of the present communication.

Before entering into details concerning individual ligaments the subject of *metamorphosis of muscles* must of necessity be inquired into.

Metamorphosis of Muscle.—Any one working for the first time at the myology of Amphibia or Reptilia must be impressed with the small amount of tendon entering into the structure of the muscles. This becomes more marked when the muscular system of an Amphibian is compared with one of the higher mammals. It would be needless to particularise any muscle or group of muscles in this respect; the fact must be obvious to any one who has devoted any attention to comparative myology.

Histologists have too long regarded muscle and tendon as distinct structures. More than one anatomist has noted how the arrangement of the fibres in tendons strongly recalls those of the fasciculi of the belly of a muscle, and it is very difficult, in examining the termination of muscle in tendon, to say how the two structures are joined, or by what means the union is brought about. Even the most expert histologists fail to find a septum

¹ Vol. xviii. Part iii.

between the carneous and ligamentous portions of a muscle, the two parts becoming so insensibly blended.

The position of tendons has an important bearing on this question:—As a rule they are situated at the extremities of muscles where contractile tissue has little opportunity of exerting itself advantageously, *e.g.*, the long tendon of the biceps at the shoulder, the elongated tendons of the long flexors and extensors of the fingers and toes. If a tendon develops in the centre of a muscle, as in the digastricus of man, it is usually in a situation where muscular tissue would be of little avail. Again, when a muscle is so circumstanced that its contractile power can be brought into play throughout its whole length, it may remain muscular in structure from origin to termination, as in the case of the intrinsic and extrinsic muscles of the tongue. If either or both extremities of a muscle fail to act to the full advantage, the very reason for the existence of such a tissue fades, and the ends degenerate into tendons to play an important part nevertheless as passive agents. Physiologists agree that the tissue of voluntary muscle is to be regarded as one of the master-tissues of the animal body. To maintain these highly specialised structures in good condition the frequent exercise of their function is necessary. Parts frequently used are, as a rule, abundantly supplied with blood, for healthy performance of function depends on the organ being adequately nourished. If these premises be correct then the conclusions which must necessarily follow are these:—The ends of certain muscles are badly situated to exert their full contractile power, or on account of modification in the creature's habits, portions of, and in some cases whole muscles become rarely used or rendered inoperative. Loss of function leads to diminished blood supply, decrease in the amount of nutrition ends in degradation of tissue. The converse of this leads to hypertrophy. The ends of muscles, when compared with the central portions, are passive; they need little blood supply, and become, in consequence, *metamorphosed into tendons*. The active central parts are often called into play, are well nourished and increase in size and quality. A very good illustration of this presents itself in the biceps flexor cubiti.

If the muscle to which the tendon belongs is one frequently

exercised, as in the case of the gastrocnemius and soleus, the attached tendon contains a very large amount of elastic tissue. If, on the other hand, the muscle degenerates from disuse, in the morphological sense of that word, the amount of elastic tissue is diminished and the parts take on the character of fibrous ligaments.

The Six-banded Armadillo (*Dasypus sexcinctus*) possesses in its hind-foot some admirable examples of these changes.

The arrangement of the muscles of the foot in this creature has attracted the attention of two writers, in particular, Mr J. C. Galton and Professor D. J. Cunningham. The last named anatomist has entered minutely into the question in his valuable research into the "Anatomy of the Mammalian Foot" contained in *The Challenger Reports*, part xvi. "Marsupialia." With regard to the foot of the Six-banded Armadillo the pith of the matter runs thus:—"The foot of this animal is of peculiar interest, from the fact that, except in the case of the hallux and minimus, the intermediate flexors and dorsal abductors have undergone regression, and are converted into fibrous tissue, so that the flexor brevis and dorsal interossei muscles are represented by fibrous bands, the reason of the transformation of these muscles being due no doubt to the manner in which the digits are bound together, limiting the power of independent movement."

The Professor also refers to Macalister's observations on *Dasypus*, regarding the first and fourth dorsal interossei muscles. In Professor Cunningham's specimen these muscles were represented by fibrous bands, in Professor Macalister's specimen they were muscular in structure as usual. It is a point of great interest, therefore, to find that the transformed muscles in some cases assume their original condition.

The *Linn. Soc. Trans.*, vol. xxvi, 1868, contains two papers by Mr J. C. Galton, one "On the Six-banded Armadillo" the other "On *Orycteropus capensis*." Both communications deal with the myology of the fore and hind limbs of these creatures. In the memoir on *Orycteropus*, certain fibrous bands are described in the sole of the foot, and are well represented in the figure accompanying Galton's paper. These fibrous bands Cunningham considers as the representatives of certain flexor muscles missing in the sole of the foot of this animal.

These facts, of which the briefest outline has been given, were of the greatest value and interest to me; and, possessing a Six-banded Armadillo in store, I proceeded to verify these observations. In the specimen examined, the flexor brevis digitorum, the inner portion of the flexor brevis hallucis and the dorsal interossei were definitely represented by fibrous bands. But the most significant fact in connection with the foot remains to be told; in the armadillo the plantaris muscle, instead of being, as in man and many animals, chiefly represented by a long, thin, and straggling tendon, is larger than the gastrocnemius. The muscle arises as usual from the back part of the external condyle of the femur (Mr Galton says internal condyle, but this is surely an oversight), it then expands into a large fleshy belly extending the whole length of the calf; at the heel it forms a tendon which glides in a well-formed groove on the back of the os calcis, and spreads out as the plantar fascia, slips of which pass to the hallux, second, and third toes, extending even to the terminal phalanges. By this remarkable arrangement the function of the flexor brevis digitorum is abrogated by the plantaris, and it degenerates into fibrous tissue. Professor Cunningham overlooks this fact in connection with the flexors, simply explaining the metamorphosis on the ground of limited movement enjoyed by the digits. This no doubt accounts for the regression of the dorsal abductors satisfactorily enough, but the dwindling of the flexor brevis needs some such explanation as is suggested above.

Guided by these facts, we must regard the glistening fibrous bands which extend ventrally and dorsally on the manus of the porpoise, as degenerate representatives of the flexors and extensors of the digits in other mammals.

Mr D'Arcy Thompson, in vol. xviii. of this *Journal*, draws attention to the fact, that in the fore-arms of the Mole the flexor sublimis muscle is metamorphosed into a powerful ligament which is made to flex the digits, in virtue of the peculiar rotatory motion given to the humerus by the teres major and pectoralis major muscles. Dr Dobson, in his admirable work on the Insectivora, gives a careful and detailed account, with figures of this metamorphosed muscle in *Myogale*.

The development of the auriculo-ventricular valves of the

heart bears testimony to the view here advocated, for they first appear as muscular outgrowths from the ventricular walls, which by degrees become replaced by fibrous and connective tissue.

It is needless to multiply examples. Sufficient facts have now been adduced from independent sources to show that tendinous and fibrous degeneration of voluntary muscles is by no means uncommon.

Dr Gadow very concisely sums up changes in muscles, such as those described above, thus :—

“Any muscle may become superfluous, either because it may be put out of action by a given position of the limbs becoming permanent, or because the work hitherto done by the muscle can be better done by neighbouring muscles, or because its special activity is not required any longer. In all these cases the muscle will become aborted, and will either form an accessory supporting part to another muscle, or it may become converted into an aponeurosis, and finally disappear without leaving any trace of its former existence.”—*Journal of Anatomy and Physiology*, xvi. 509.

Let me now address myself to the task of showing that many of the ligaments about the shoulder arise from muscles.

If the demonstration be commenced by discussing those points which are plain and self-evident, proceeding thence to consider those which are more intricate, the inferences will not be so likely to appear as though overdrawn or far-fetched, for what is true in the simple instance will appeal with almost equal force to that which is complex.

The Coraco-Brachialis.

This muscle presents itself as an excellent example whereby to illustrate the question. Thanks to the labours of Professor Wood, the history and constitution of this muscle have been expounded in an able and very satisfactory manner in the *Journal of Anatomy*, vol. i., 1867, where it is conclusively shown that the muscle in mammals has for the most part a triple constitution. Ordinarily the muscle arises from the tip of the coracoid process of the scapula in company with the short head of the biceps, with which it is joined for some distance. The muscle is inserted into the inner border of the humerus near its

middle, between the origins of the triceps and brachialis anticus muscles. Some of the higher fibres are attached to a fibrous band which forms an arch over the tendons of the latissimus dorsi and teres major muscles, the fibrous loop extending from the coracoid process to the lesser tuberosity of the humerus. Viewed in the light afforded by a study of the variations this muscle is subject to in the human body, and information gained from comparative myology, the coraco-brachialis presents three parts.

1. The portion represented by the fibrous loop may develop as a distinct muscle attached to a lesser tuberosity of the humerus and known as the *rotator humeri*.
2. The middle portion is the *coraco-brachialis* of ordinary human anatomy.
3. The third piece may exist as a muscular belly extending from the common tendon to the internal condyle of the humerus. It is rare to find this piece fully developed, its situation being marked out by the fibrous band which commonly extends from the lower part of the muscle to the elbow, and is familiar as the *internal brachial ligament* of Struthers.

Here, then, is as good an example of regression of muscle as is afforded by the Armadillo, the fibrous bands now and then declaring their ancestry by persisting as muscles either wholly or in part.

The ligaments at the shoulder-joint will now be considered, commencing with the

Gleno-Humeral Band.

Anatomists have long been aware that the Frog possesses in its shoulder-joint a ligament very much resembling the ligamentum teres in the hip-joint. This structure is often represented in the shoulder-joint of man by an accessory band, as some writers regard it, known as the gleno-humeral ligament, having the following attachments :—Above it springs from the edge of the glenoid fossa at the root of the coracoid process, and passes downwards to the lesser tuberosity of the humerus. It runs parallel with the long tendon of the biceps, and forms, in the usual condition of the parts, a distinct bulging into the joint, separated from the synovial cavity by the thin serous membrane only. Occasion-

ally the ligament is completely surrounded by the synovial membrane, and forms as prominent a structure in the joint as does the biceps tendon; indeed, it then becomes a veritable *ligamentum teres*. This condition seems, according to my own dissections, far more frequent in the fœtus than in the adult. I have also met with it in the condition of a *ligamentum teres* in the shoulder-joint of the common Wombat (*Phascolomys wombat*), in the Galago (*Galago maholi*), the Opossum (*Didelphys philander*), in the Hedgehog (*Erinaceus europea*), and in *Chlamydophorus truncatus*.

Facts will now be adduced to show that in all probability this gleno-humeral ligament is the *tendon of insertion of the subclavius muscle*. The interesting amphibian, *Menobrachius lateralis*, presents about the shoulder a very distinct muscle, having the following attachments:—It arises from the ventral surface of the long precoracoid cartilage, and passes backward, to be inserted into the head of the humerus, between the deltoid, pectoralis major, and supraspinatus muscles, as shown in fig. 1. Mr Mivart, in his paper on the myology of this creature, identifies this muscle as the *subclavius*. Whether it deserves this name, or that of *epicoraco-humeral*, is a matter of little moment, but its situation and points of attachment are, for the purposes of this paper, of great importance. It seems to me that this muscle is the ancestor of the subclavius of mammalian myology. If any one objects to the propriety of descending so low in the scale of vertebrate life as that occupied by *menobrachius*, to draw conclusions regarding muscles in man, let me refer him to a statement of Professor Humphry, in vol. vi. of this *Journal*, where, in writing on the myology of *Cryptobranchius japonica*, he draws attention to the probability of the remarkable tendinous inscription in the semimembranosus of man being homologous with a similar inscription in the great flexor and adductor muscle of the leg of that creature, which corresponds with the gracilis, semitendinosus, and semimembranosus of mammals (page 19).

Let the shoulder-joint of a pigeon or some such bird be next dissected.

Arising from the dorsal portion of the keel and median portions of the body of the sternum is a broad, flat sheet of muscle, which passes forward as a strong tendon through the

bony foramen formed by the union of the scapula, coracoid, and clavicle; emerging from this osseous ring it is inserted into the dorsal surface of the head of the humerus in the immediate neighbourhood of the attachment of the pectoralis major; the tendon, after traversing the foramen triosseum, *lies within the capsule of the joint*. The muscle corresponding to this description enjoys a variety of names, as *pectoralis secundus*, *levator humeri*, and *subclavius*. Its attachment, appearance, and relations are shown in fig. 2. The *Linn. Trans.* for 1868, vol. xxvi., is enriched by a paper from Prof. Rolleston, "On the Homologies of Certain Muscles connected with the Shoulder-joint," in which it is most conclusively shown that the muscle, whose main function it is to raise the wing, is homologous with the subclavius and not with the pectoralis minor muscle.

Turning now to man we find a muscle arising from the costal cartilage of the first rib, passing thence beneath the costo-coracoid membrane, but above the coracoid process of the scapula, to be finally inserted in the ordinary course into the under surface of the clavicle near the acromial end, in contact with the attachment of some strong fibrous bands known as the coraco-clavicular ligaments; this muscle is the subclavius.

The point of insertion occasionally varies, the muscle ending in the coracoid process near its base, instead of going to the clavicle, the variation being one recognised in human anatomy. This unusual arrangement affords the key, as these variations often do, whereby the morphologist may receive direction and guidance in his interpretations. The explanation runs thus:—The coraco-clavicular ligaments (conoid and trapezoid) are degenerate fibres of the subclavius, and they form the bridge or connecting link by which the subclavius muscle and the gleno-humeral ligament become continuous. A little dissection, especially in fetuses, often shows that this gleno-humeral band is continuous with the coraco-clavicular ligaments, and as the muscle is in intimate relation with these bonds, the inference is clear that *the gleno-humeral ligament is the divorced tendon of the subclavius muscle*. Fig. 3 shows the muscles and ligaments in the relation they bear to each other normally.

In the shoulder-joint of two young crocodilians (*Crocodilus acutus* and *Alligator mississippiensis*) I found a well-marked

ligamentum teres lying inside the capsule. It arose from the scapula anterior to the glenoid fossa, and was attached to the head of the bone near the anterior tuberosity. This band was strong and unconnected with any muscle. Its existence is noteworthy in an animal lacking a clavicle and any representative of a precoracoid.

Before closing the evidence bearing on the relation of the subclavius to the gleno-humeral ligament, it is absolutely necessary to dispose of another band lying in relation with the capsule of the shoulder-joint known as the coraco-humeral ligament. This presents little difficulty.

The coraco-humeral band springs from the coracoid, having an attachment from the base to near the tip of that process; passing thence *over* the capsule, it is inserted into the outer tuberosity of the humerus.

The pectoralis minor muscle, as a rule, finds an attachment to the upper border of the coracoid process, but now and then it glides as a tendon over this bony prominence to blend with the capsule of the joint, or ends in a tendon to be attached to the great tuberosity of the humerus.

Fig. 4 represents this condition as seen in the Capuchin (*Cebus albifrons*). In very many of other monkeys it is the normal conditions. Professor Macalister, in an interesting paper in this *Journal*, vol. i, 1867, entitled "Notes on an Instance of Irregularity of the Muscles around the Shoulder-joint," reviews several recorded instances of this abnormal arrangement of the pectoralis minor, and hints that the gleno-humeral ligament belongs to this muscle; but this view of the matter is invalidated on two points. Firstly, the pectoralis tendon when it takes this unusual course lies outside the capsule, whereas the gleno-humeral ligament lies within it. Secondly, it cannot be the homologue of the tendon of the levator humeri of birds, as Professor Macalister makes out, for Rolleston has shown so satisfactorily that the pectoralis minor of man is not the homologue of the avian levator humeri, that a recent text-book of Zootomy calls the muscle that raises the bird's humerus, subclavius. The relations of the pectoralis minor to the capsule in man and in monkeys lead me to believe that the coraco-

humeral ligament is the tendon of that muscle metamorphosed into a fibrous band.

The Rhomboid Ligament.

Having disposed of the outer end of the subclavius muscle, some attention must now be devoted to the inner portion in order to study the relation it bears to the band of fibrous tissue which unites the first costal cartilage to the clavicle, called, on account of its shape, the rhomboid ligament. It is in the opossums that the key-note is struck whereby we may seek to unravel the history or pedigree of this apparently wayside structure.

Whilst dissecting the muscles about the shoulder of the Opossum (*Didelphys philander*), it was observed that the usual situation of the rhomboid ligament was replaced by a muscle, which arose from the costal cartilage of the first rib, and was inserted into the under surface of the clavicle.

The relations of clavicle and sternum in *Didelphys* are somewhat complicated, but are full of interest, as they probably explain the degenerated condition of this muscle in the higher mammals.

Fig. 5 is intended to represent the upper part of the sternum, and the costal cartilages in relation with it and the clavicles, which, instead of abutting on the sternum through the intervention of an interarticular fibro-cartilage, are connected therewith by two ossicles which replace the discs in question, these ossicles in their turn are attached to the top of the sternum by ligaments, synovial cavities being developed between each of these bones and the top of the sternum, also between these bones and the inner end of the clavicle. Briefly it amounts to this, the interarticular fibro-cartilages of man's sterno-clavicular joint are represented in this animal by bones, the number of synovial cavities remaining the same.

The clavicle in the opossum by this arrangement is able to move freely on this intercalated ossicle (omosternum, Parker), aided by the subclavius and the muscle described above, which I propose to term the *costo-clavicular*, in reference to its points of attachments.

Passing upwards to man, the office of the costo-clavicular muscle becomes abolished, and its fibres become represented as a ligament. In many animals where this composite condition of the clavicle does not exist, the subclavius arises from the side of the sternum and fills up the space between the costal cartilage and the clavicle, and it is on this ground that the costo-clavicular muscle is to be regarded as a segment of the subclavius, therefore the rhomboid ligament has the same origin, and is to be regarded as a segment of the inner end of the same muscle. If some anatomists should consider that the costo-clavicular muscle is rather a representative of the upper segment of a *rectus sternalis*, which in the opossum is well developed, but ends definitely at the lower border of the first rib, it will be well to remember that Professor Rolleston was well aware that the subclavius does in some cases borrow elements from that muscle, so that if the ligament in question arises from regression of the upper end of a rectus sternalis, it will invalidate but little the argument here set forth.

Viewed in the full bearings of this speculation, the history of the subclavius is as instructive as a muscle could well be. It is advisable, therefore, briefly to summarise the conditions. Commencing with the menobranchus, we see it as a muscle arising from the precoracoid, and at its insertion enveloping the outer aspect of the head of the humerus, being of muscular structure throughout.

Next we see it luxuriating in fullest perfection in flying birds, its distal end metamorphosed into tendon, the muscle performing the laborious and important function of raising the wing.

Lastly, in man it becomes reduced to almost insignificant proportions, lying as a small second-rate muscle under the clavicle, and representing in its retirement the middle portion only of the bird's *levator humeri*, its proximal end degenerated into a uniting bond to connect the clavicle with the first costal cartilage, whilst its outer end is represented by the coraco-clavicular ligaments, and the small insignificant band, so far as function is concerned, known as the gleno-humeral ligament.

The Coraco-Acromial Ligament.

Arising from the outer border of the coracoid process of man's scapula, and passing over the head of the humerus to be attached to the under surface of the tip of the acromion, is a strong band of ligamentous fibres one-fourth of an inch broad on an average.

This band is commonly known as the coraco-acromial ligament, and the office usually ascribed to it is, that it limits undue movement of the head of the humerus upwards, thereby preventing dislocation of that bone.

Whether this be so or no, I do not intend to argue, but Mr St Geo. Mivart, in his work on *Elementary Comparative Anatomy*, draws attention to the fact that this band of fibrous tissue is the representative in man and many animals of the curious hoop-like prolongation of the acromion which arches downwards to join with the coracoid process of the scapula in the Two-toed Sloth. Therefore it seems to be of greater morphological significance than of functional value.

The Transverse Ligament.

The ligament which converts the small suprascapular notch into a foramen for the transmission of the nerve of that name is of interest, for it probably arises in two different ways.

1. It may be regarded as some of the fibres of the supraspinatus muscle, which have become converted into fibrous tissue. This view of its nature is supported by the condition of the parts in the porpoise.

2. It is well known that in the sloths the foramen is completely surrounded by bone, as sometimes occurs in man.

In a young Ant-eater (*Myrmecophaga jubata*) I had an opportunity of examining, the foramen was composed in part by the body of the scapula and completed by the coracoid process, thus affording an interesting example in the limbs of a passage of a nerve between two centres of ossification, a condition almost constant in the skull. Therefore I am disposed to the

view that the transverse ligament is the fibrous representative of this bony bridge constant in sloths, and that the occasional occurrence of a complete osseous foramen in this situation is not to be regarded as an ossification of the transverse ligament, but as a reversion to a former condition.

This view receives some support from the supracondyloid foramen in the humerus of many animals. In the lion, at birth the foramen is formed in its upper part by a bony outgrowth from the humeral shaft, the lower half is completed by an osseous projection from the lower end of the humerus below the epiphysial line, the two projecting arms forming by their union the foramen in question (fig. 6). In man, the most frequent condition of this foramen, when it exists, is to have the upper part of the ring formed of an osseous outgrowth of the shaft of the humerus, and known as the supracondyloid process, the lower part of the ring being completed by a band of fibrous tissue extending to the internal condyle, and often affording attachment to the pronator radii teres muscle (fig. 7). This foramen, and that at the upper border of the scapula, seem to be, so far as their mode of formation is concerned, exactly parallel, the ring sometimes existing as bone, at other times part of the osseous material being replaced by ligament.

It is by no means a novel suggestion, that osseous parts in one animal may be represented by fibrous tissue in another. Professor Humphry, writing on the "Myology of the Limbs of Unau, the Ai, the Two-toed Ant-eater and the Pangolin," in this *Journal*, vol. iv., 1870, writes:—"The gradations of the clavicle in the four creatures are curious. In manis it is absent; in ai it is a mere scale attached to the inner edge of the coracoid, which is large, and projects forwards to the inner end of the acromion. A *long ligament* the *remnant* of the structures of which its proximal end was originally composed, connects its inner end with the sternum. In Unau the clavicle is articulated externally with the acromion, which remains continuous with the coracoid, and is much longer; still it does not quite reach the sternum, a strong *ligament* the *degenerated* omosternum of Parker connecting it with the sternum."

These examples afford conclusive evidence of bony parts being

represented by ligament; other cases readily suggest themselves to the mind of the comparative anatomist.

Briefly, the antecedents of the ligaments about or near the shoulder-joint may be summarised thus:—

1. The *lower* portion of the coraco-brachialis muscle is responsible for the *internal brachial ligament* of Struthers.

2. The *fibrous loop* passing from the coracoid to lesser tuberosity of the humerus, arching over the tendons of the latissimus dorsi and teres major muscle, represents Wood's *rotator humeri*.

3. The *gleno-humeral ligament* is the divorced tendon of the *subclavius* muscle.

4. The *coraco-humeral band* represents the original insertion of the pectoralis minor muscle.

4. The *rhomboid, conoid, and trapezoid* ligaments arise by regression of the *muscular fibres* of the *subclavius*.

6. The *transverse ligament* of the scapula is formed either by metamorphosis of fasciculi of the *supraspinatus* muscle, or represents the *bony bridge* constant in sloths, and occurring as a variation in man.

7. The *coraco-acromial band* represents the *bony loop* which connects the two processes in the Two-toed Sloth (Mivart).

8. The *interclavicular ligament*, the *interarticular fibro-cartilages* at the sternal and acromial ends of the clavicle represent *aborted bony segments* belonging to the pectoral girdle (see Parker's *Shoulder-Girdle and Sternum*).

9. The *ligamentous band* extending from the tip of the coracoid process to the costal cartilage of the first rib, occupying the free edge of the costo-coracoid membrane, is the fibrous representative of the long *coracoid* of birds and monotremes (Gegenbaur and Rolleston) (fig. 3).

10. The fibrous loop running from the tip of the supra-condyloid process of the humerus (when present), represents the lower bony part of the foramen as it exists in many other animals.

SECTION II.

The Migration of Muscles and its Relation to Ligaments.

The term "migration of muscles" may be defined as:—The changing of the situation of a muscle by alteration of its origin or insertion.

Dr Hans Gadow, in an interesting paper on "Comparative Myology," in vol. xvi., 1882, of this *Journal*, gives some examples of the process, and states that as a rule the origin is more subject to variation than the insertion of a muscle. My own observations lead me to concur with this statement.

Dr Gadow chooses for illustration the ambiens muscle. In alligators this muscle arises from the anterior superior spine of the ilium, but in *Hatteria* (sphenodon) and in *Testudo*, from the *processus lateralis pubis*. In *Monitor*, *Lacerta*, and others, from the inner and ventral aspect of the preacetabular part of the ilium, close to the acetabulum. While in other Saurians, as *Iguana* and *Chameleon*, its origin has passed over to the acetabular part of the os pubis.

But by far the most important contribution to our knowledge in this respect is afforded by Dr Ruge of Heidelberg in an admirable paper entitled "Untersuchung über die Extensorengruppe am Unterschenkel und Füsse der Säugethiere" published in the *Morph. Jahrbuch* for 1878.

Here Dr Ruge satisfactorily traces out the history and ancestry of the extensor brevis digitorum muscle. He shows that in the *Monotremata* this muscle belongs to the peroneal group, and arises entirely from the fibula. Ascending the scale of mammalian forms we find the muscle passing down tendon by tendon until it reaches the condition presented in the foot of man.

Having recently enjoyed the opportunity of dissecting a *Koala* (*Phascolarctos cinereus*), in which animal the muscle in question presents an intermediate condition of this interesting process; it will be well to describe it by way of illustration. Reference to fig. 8 will show the extensor longus digitorum arising from the external tuberosity of the tibia and the head of the fibula to be inserted as usual into the four outer digits. The extensor brevis digitorum is seen as a tiny muscular slip aris-

ing from the outer aspect of the os calcis, then dividing into two tendons to be attached to the long extensors destined for the syndactyle second and third digits. The remaining portions of the short extensor arise as separate muscles from the head and outer surface of the shaft of the fibula, being limited to the upper third. They degenerate into delicate tendons to pass with the peronei muscles behind the external malleolus, to be distributed to the fourth and fifth digits. These two muscles are usually referred to as *peroneus quarti metatarsi* and *peroneus quinti metatarsi*. It seems to me that one of the great points in Ruge's investigation is that it shows clearly that the fourth and fifth peronei muscles, thought to be absent in man, have really descended from the fibula, and help to make up his extensor brevis digitorum. Man's peroneus tertius is a muscle almost, if not exclusively, human, and is to be regarded as that portion of the extensor brevis which belongs to the fifth toe, but, contrary to its companions, has not descended on to the dorsum of the foot. Its origin from the anterior surface of the fibula does not negative this conclusion, for Ruge points out that the peronei in *Monotremata* arise from the anterior surface of the fibula, but in the opossums they have wandered to the outer side.

Dr Cunningham has discussed these relations very fully in his *Report on the Marsupialia*, and substantiates them by his own dissections so far as relates to *Thylacinus* and to *Cuscus*. In the first-named animal the extensor brevis digitorum arises from the fibula; in the cuscus the part belonging to the medius and index has reached the dorsum of the foot, whilst that portion belonging to the two outer digits still shows a fibular origin, thus repeating the condition seen in the koala.

Whilst engaged dissecting a Koala and an Armadillo (*Dasypus sezzinctus*), in order to verify some of these arrangements for my own satisfaction, I was led to observe an additional example of migration.

In both these animals the tibialis posticus muscle is described as being double. Wood, Cunningham, and Galton found the same thing in the example of *D. sezzinctus* dissected by each of them. Young describes the duplicity of this muscle in the Koalas he dissected. In my specimens two muscles arose from the posterior surface of the shaft of the tibia, and partly from the

fibula. The inner one, much the larger, was attached to the upper two-thirds of the tibia, and partly to the head of the fibula, then becoming tendinous passed behind the internal malleolus to be attached to the inner side of the base of the first phalanx of the hallux, having a very large sesamoid bone developed in the tendon where it passed along the inner side of the scaphoid bone (fig. 9).

The second muscle, much smaller, arose from the posterior surface of the tibia and fibula near their heads, formed a thin tendon which passed in a groove behind the internal malleolus, external to the foregoing muscle, and finally was inserted into the scaphoid bone.

The only difference in the two animals was this: in the Koala the sesamoid was very much larger than in the Armadillo. The two animals agree in this respect, that neither possessed an *abductor hallucis muscle*.

In Galton's specimen the abductor hallucis was not clearly or distinctly defined, and the muscle figured by Cunningham is not only a small and insignificant structure as compared with mammals generally, but does not quite agree with the abductor hallucis in its mode of origin.

It seems to me that this so-called double tibialis posticus either represents by its inner portion an abductor hallucis arising from the tibia, or else it abrogates the function of the short muscle usually bearing that name.

It is noteworthy in this respect, that in my Koala there was no short abductor to the hallux, and in Professor Cunningham's figures the muscle is represented as arising from the large ossicle on the inner side of the scaphoid. Certainly this does not correspond with the abductor hallucis as it is usually seen! Hence it would be more in accord with these facts, aided by the light of Ruge's observations on the short extensor, to consider that the abductor hallucis in these animals arises from the posterior surface of the shaft of the tibia, winds behind the internal malleolus, then develops a sesamoid bone in its tendon, where it plays over the scaphoid, and is inserted into the first phalanx of the hallux, the sesamoid bone often affording attachment to a slip of the flexor brevis hallucis, which thus *simulates a short abductor hallucis*.

There are yet other reasons for believing that the abductor hallucis is an "emigrant" muscle, as it exists in the sole of the foot of man. In the hand it is the normal condition for the abductor pollicis to arise from the ridge on the trapezium, and the annular ligament passing thence to be inserted into the radial side of the base of the first phalanx of the pollex. Often the muscle in question deviates from this arrangement by taking origin in part from some one tendon or other about the wrist. Frequently it is connected with the extensor ossis metacarpi pollicis, occasionally with the palmaris longus, and it has even been seen arising from the styloid process of the radius. Dr Dobson points out that in the Mole the palmaris longus sends a slip to the pollex. When the muscle contracts the pollex is abducted by virtue of this arrangement. In this aspect it seems to be fairly obvious that this muscle has, at some time or other, wandered from an original attachment to the bones of the forearm to its present position on the carpus.

There is little doubt that the abductor pollicis and abductor hallucis are homologous, and it is interesting to find both muscles offering evidence of a change of origin from a proximal to a distal segment of the limb. If this way of regarding these muscles be correct, the radial head of the flexor brevis pollicis and the tibial portion of the flexor brevis hallucis must be looked upon as the abductores in the intrinsic mechanism of manus and pes respectively.

Before leaving the Koala there is just one point more in the anatomy of its hind-limb which has a very important bearing. Wedged in between the lower end of the fibula and the astragalus is a fibro-cartilaginous disc, one end of which, becoming gradually thinner, merges into the lower end of the peroneo-tibial muscle, which in this animal replaces the interosseus membrane, and forms a well-developed muscle, exceeding in this respect the corresponding muscle in the Wombat (fig. 8).

In several animals I have had the opportunity of dissecting, notably the Great Ant-eater (*Myrmecophaga jubata*), the popliteus muscle is continuous with, by means of its tendon, the external semilunar fibro-cartilage of the knee-joint, and in the bull frog the semi-membranosus muscle is, in the same way, in direct continuity with the internal disc. For a long time the opinion

was in my own mind, that these discs had some other significance, but by the indications afforded by the disc in the ankle-joint of the koala, it will probably turn out that they have a muscular origin also. Among other examples of "migrations" of muscles, the peroneus longus, tibialis anticus, and extensor longus digitorum must be cited as clear and indisputable cases.

In my previous paper it was pointed out that the external lateral ligament of the knee-joint is formed by the peroneus longus muscle acquiring a new attachment to the fibula, its original point of fixation being the femur, and subsequent observations support that view strongly. The tibialis anticus muscle in man and the majority of animals arises from the tibia, but in the horse among mammals, and the ostrich among birds, this large and important muscle springs by a strong and powerful tendon from the external condyle of the femur (fig. 10). The extensor longus digitorum in very many animals, even in some of the anthropoid apes, such as the Orang, arises from the femur instead of limiting itself to the bones below the knee, as in man. In the Ostrich and other birds it arises from the femur (fig 10).

Not to multiply instances, these three muscles illustrate in a positive manner that muscles are exceedingly prone to migrate particularly with regard to their origin. This interesting process of the shifting of muscles from one attachment to another affords evidence of an additional mode by which muscles, or parts of muscles, may become converted into ligaments. In this way it seems to me that the ligaments about the ankle-joint have been formed, that many, certainly the more important, muscles about the sole of the foot, have had, at some time or other, an origin from the bones of the leg, and that in the progress of "slipping down," a part of their tissue has been utilised to form ligamentous bands, which later become developed as independent structures, and in the clear light afforded by comparative anatomy we can read the history of the formation of some of these ligaments as distinctly as any process written in the "book of nature."

With regard to some structures in the lower limbs of a more or less ligamentous nature, their ancestry may be arranged thus:—

1. The *plantar fascia* results from the modification of the distal and of the *plantaris muscle*.

2. The *palmar fascia* represents tendons of the *palmaris longus* which used to go to the digits. (This example is placed here for comparison.)

3. The *posterior ligament* of the superior tibio-fibular articulation results from the regression of the *rotator fibulae muscle*.

4. The *transverse ligament* of the inferior tibio-fibular articulation represents the lower end of the *peroneo-tibial muscle*. The *posterior fasciculus of the external lateral ligament* of the ankle-joint probably has a similar origin.

5. The *anterior and middle fasciculi* of the *external lateral ligament* of the ankle-joint are probably derived from the *extensor brevis digitorum* as it slipped from the fibula on to the dorsum of the foot.

6. The *internal lateral ligament* of the ankle-joint in all probability has its origin from some of the short flexor muscles of the sole of the foot, such as the *abductor hallucis* or *flexor brevis digitorum* muscles when they migrated from the leg to their later situation in the plantar region.

The Inferior Calcaneo-Scaphoid or Spring Ligament.

In the hind-limb of a Frog most of us are aware that the astragalus and os calcis present the anomalous condition of long bones, and, lying side by side, recall in a marked degree the relations of the radius and ulna to one another as seen in man.

Fig. 11 represents the os calcis, astragalus, the remaining portion of the tarsus with the five metatarsals, and the additional ossicles found on the inner side of the foot of the Frog. The specimen from which the drawing was made was a Bull-frog, and the parts are represented of natural size.

Arising from the under surface of the os calcis and astragalus is a well-developed muscle. It ends in a strong tendon, which passes over the tarsus to be inserted chiefly into the bases of the first and second metatarsal bones. This muscle I shall term *calcaneo-metatarsal*. More than once I refused to allow myself to believe that this muscle was the "ancestor" of the *spring ligament*, and possibly also of the *calcaneo-astragaloid ligament* in the foot of man. Morphologists, as a rule, consider the wonderfully rich muscular system of the Frog too specialised for enabling conclusions to be drawn respecting man. Let us

consider awhile. In the group of lemurs are placed two curious forms, *Tarsius* and *Galago*, whose tarsal bones present a condition somewhat resembling the Frog. I have had an opportunity of dissecting *Galago*, and shall confine my remarks to that animal. The *os calcis* and scaphoid are very elongated, but the astragalus is fairly normal in shape, as seen in fig. 12. In the place of the calcaneo-metatarsal muscle is a broad ligament containing an abundance of yellow elastic fibres; it represents in a ligamentous form the large muscle of the Frog's foot. The inferior calcaneo-scaphoid ligament of the human foot arises from the anterior and inner extremity of the *os calcis*, and is attached anteriorly to the under surface of the scaphoid bone. In this it agrees with the condition of the ligament as seen in the *Galago*, except that in this lemur it is a much broader structure relatively.

Comparing the *Galago*'s foot with that of the Frog we shall see that the calcaneo-metatarsal muscle of the batrachian's foot has the same relations posteriorly as does the ligament in the lemur. Anteriorly it differs, inasmuch as it gains an attachment to the metatarsus, whilst its strong tendon supports that portion of the tarsus lying immediately behind the metatarsus. All this difference may depend on the diversity or arrangement of the tarsal bones in the two forms described, yet it seems legitimate in this case, as in the other examples of metamorphosed muscles discussed, to consider that in all probability the Frog's calcaneo-metatarsal muscle is the ancestor of the *inferior calcaneo-scaphoid ligament* in the foot of man. After reviewing these facts it may not appear presumptuous or untimely to generalise in the following manner:—

Muscles, particularly those of the limbs, and more especially those of the distal segments, are prone to conduct themselves in three diverse ways.

- 1st. Their extremities, or the greater part of their structure, may become metamorphosed into tendon.
- 2nd. The points of origin may shift from their original situation. This affects the proximal end far more frequently than the distal one.
- 3rd. Whole muscles may have their function abrogated, and their structure becomes converted into fibrous tissue.

The three processes may be termed, for the sake of con-

venience, "metamorphosis," "migration" and "regression." Any one of these three processes may result in transforming an inactive muscle, wholly or in part, into a passive ligament, to act as a means of union between any two parts of the skeleton.

Whilst working out these metamorphoses the truth of the following statement, usually accredited to Müller, seemed to appeal with great force:—"Comparative Anatomy in its complete form leads to such necessary consequences, that expressions may be found for organisations which are like the expressions of an equation. If these expressions are found, the unknown quantities may, in a given case, be reckoned from the known."

All points in the anatomy of animals mentioned in this paper, with the exception of *Thylacinus* and the Monotremes, I have directly verified by my own dissections, so as to be responsible as far as possible for the statements made.

In the Bibliography is appended a list of the more important works and memoirs which have been to me of the very greatest assistance in working out the history and ancestry of some of the ligaments of the human frame; the help and guidance these writings have afforded me in my dissections I cannot too gratefully acknowledge.

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To my friend Mr Wynter is due all credit for the drawings which illustrate this paper, and I must heartily thank him for the care and pains he so willingly bestowed upon them.

EXPLANATION OF PLATE III.

Fig. 1. The left scapula and upper limb of *Menobranthus lateralis*, showing the subclavius muscle arising from the præcoracoid cartilage. $\times 2$.

Fig. 2. The coracoid, with part of the clavicle and head of the humerus of *Rufous tinamon*, showing the subclavius muscle and the tendon traversing the "foramen triosseum."

Fig. 3. The upper part of the thorax and pectoral girdle, with the heads of the humeri of a human fœtus at birth. On the left side the rhomboid ligament R, the subclavius muscle, the coraco-clavicular ligaments, and the gleno-humeral band are shown. On the right side the long coracoid ligament LCL is represented.

Fig. 4. The left scapula with the head of the humerus of a monkey (*Cebus*) designed to show the pectoralis minor muscle PM being attached in part to the coracoid process, and in part to the head of the humerus.

Fig. 5. The top of the sternum and clavicle of an opossum (*Didelphys philander*), to show the relation of the costo-clavicular muscle to the subclavius.

Fig. 6. The humerus of a still-born lion (*Felis leo*), to show that the upper part of the supracondyloid foramen is formed from the

diaphysis, and the lower part is completed by the epiphysis in the adult, but in this young specimen it is cartilaginous.

Fig. 7. The lower end of a humerus from a man, to show that the lower part of the bony supracondyloid foramen of the Carnivora and other animals may be represented in man by ligaments.

Fig. 8. Front view of the leg of koala (*Phascolarctos cinereus*), designed to show a part of the extensor brevis digitorum on the dorsum of the foot, and two of its tendons still attached high up on the fibula. The peroneo-tibial muscle and the interarticular fibro-cartilage at the ankle-joint are shown.

Fig. 9. A view of the inner side of the leg of koala, showing the abductor hallucis arising from the fibula, passing behind the inner malleolus, having a large sesamoid developed in the tendon where it plays on the side of the scaphoid, then sending a slip on to the base of the first phalanx of the hallux. The tibialis posticus is inserted as usual into the scaphoid bone.

Fig. 10. The left knee-joint of an ostrich (*Struthio camelus*), showing the extensor longus digitorum and tibialis anticus muscles arising from the femur.

Fig. 11. The tarsus of a bull frog, to show the calcaneo-metatarsal muscle (CM) and its attachments.

Fig. 12. The astragalus, calcaneum, and scaphoid of *Galago maholi*, to show the calcaneo-scaphoid ligament.

OSTEOLOGY OF *NUMENIUS LONGIROSTRIS*, WITH
NOTES UPON THE SKELETONS OF OTHER
AMERICAN LIMICOLÆ. By R. W. SHUFELDT, *Captain*
Med. Corps, U.S. Army; Memb. American Ornithologists'
Union; Memb. Society of Naturalists, E.U.S.; Memb. Ento-
mological Society of Washington, &c. (PLATES IV. and V.)

My first acquaintance with the long-billed curlew occurred nearly twenty years ago, yet the introduction made such a vivid and pleasant impression upon my mind, that I venture to say the picture will probably never be effaced from my memory. The ground was sacred ground, too, to all ornithologists, for, if my recollection serves me right, Audubon had once paced over the same spot, and many of the scenes he drew were flashing before me at the time,—the very realities of his work.

I had made a hasty landing—for a storm was brewing—upon the long, low beach, that faces seaward, of Egmont Cay, on the west coast of Florida. The air was cool and the sea quiet, while the great stretch of white sand beach stood out in marked contrast with the lowering sky that formed its background. Leaving the men with the boat, I determined to skirt the shore as rapidly as possible, so as to return to the vessel before the storm broke.

Hardly had I proceeded a hundred yards when my attention was attracted to a scattered flock of birds, some ten or fifteen in number, approaching the beach from the direction of the sea. Their outstretched and almost motionless wings flashed a deep chestnut in the strange light of the storm. They lit some distance ahead on the beach, without giving vent to any note, but at once started to lead me at a rapid pace. It was not until this time that I recognised the members of the company, and I said aloud in my excitement—"They are long-billed curlews, yes, and a few godwits with them!" Without appearing to regard their movements, I hastened along, for the ground admitted of no concealment whatever, in their direction. They were at least two hundred yards in advance; and so intently was I observing their action, that another flock of birds, if anything still more

interesting to me, coming from a direction I could hardly tell where, suddenly alighted about half-way between us. This party consisted of two magnificent roseate spoonbills, accompanied by several oyster-catchers. Our surprise was mutual, and I at once saw that these last arrivals on the scene, as soon as they recovered their senses, intended to take flight again; so without any warning, and in sheer desperation, I ran as hard as ever I could up the beach towards them. When within about fifty yards, away they flew, followed, I assure you, by the contents of both barrels of my fowling-piece, but all to no avail. They were joined by the curlews as they passed, and I was obliged to return empty-handed.

This was the last occasion of my meeting with the long-billed curlew on our Atlantic coast, and many years passed by before it was again brought to my notice. In June 1877 I formed, as surgeon, one of a party of troops and Indians, scouting through the central portion of Wyoming territory. Having galloped off by myself one day, away from the command, over the undulating but treeless prairie, my ears were suddenly saluted by the cries of one of these birds as it sailed over my head. Its peculiar rattling note soon caused several birds of the same species to appear and sail over me in a like manner. Their flight at these times was very steady, and unaccompanied during a good part of it by any movement of the wings. Dismounting from my horse, I shot at them several times with my carbine, as they passed directly over me in their slow and steady course, and, after a few shots, I had the satisfaction of so crippling the wing of one, as to cause him to fall and become my game.

Their nests or young were evidently in the neighbourhood, but my search for them proved fruitless, and I never saw either during my entire stay in that country or since. Three years later, at Fort Fetterman, Wyoming, while collecting one day in May, just beyond the buildings of the garrison, eight of these birds came by me. They were in close range, and my first shot broke the wing of one, which, after it had recovered itself from its sudden fall, cried out vehemently to its companions for aid. These flew in a most confused manner about me, until I had secured six of their number in all. From these specimens I made three or four good skeletons, and one exceptionally fine skin.

The description of the former will form the subject-matter of this paper, while the latter now stands up as large as life in the ornithological collection of the Smithsonian Institution.

The genus *Numenius* is quite a cosmopolitan one, and some twelve or fifteen species of curlews are found in various parts of the world. In England two very well known forms occur, *N. arguata* and *N. phaeopus*; the latter has been recently added to the fauna of this country.

At the present writing, our avifauna has this genus well represented by the five species found in it. These are *N. longirostris*, *N. hudsonicus*, *N. borealis*, all of pretty general distribution over the United States, and *N. phaeopus* and *N. taitensis* confined to certain localities—the whimbrel having been taken in Greenland.

Curlews fall into one of the groups of the great order of grallatorial birds. The order Gallatores comprises all those forms usually known to us as waders. They possess one character that applies nearly universally to all its members. This is the nakedness of the suffrago, or that part of the leg just above the heel. The degree of this nakedness varies in the different species; in *Numenius* it is very well marked. Ornithologists have found that the numerous, and in many cases extraordinary, forms, that comprise this order Grallatores, fall more or less naturally into three groups.

The first of these, and the one to which our curlew belongs, is known as the LIMICOLÆ. In it we find all the snipe-like and plover-like birds, together with such forms as *Hæmatopus* and *Recurvirostra*. They are generally designated as the *shore birds*, and possess in common many characters and habits. In the classification of Huxley, these birds comprise the Schizognathæ, having certain cranial characters, which I have elsewhere applied and enunciated in an American form of plover.¹ Sometimes they lack the intrinsic muscles of the lower larynx, and are said never to possess more than one pair of them.

Our second group of grallatorial birds is made up of the HERODIONES, containing, as it does, the herons and forms more or less nearly related to them. Finally, we have the sub-order

¹ "Observations upon the Osteology of *Podasocys Montanus*," *Jour. Anat. and Phys.*, vol. xviii. pp. 86-102, plate v.

or group, the ALECTORIDES, represented by the cranes, the rails, and other kindred forms. It does not lie within the scope of this monograph to present the characters of these last two groups, so they will be omitted here.

Believing, as I do, that it is always an advantage to present a concise account of the leading external characters of the bird whose skeleton we are about to describe, I find that in the present instance I can do no better than repeat the words of so eminent an ornithologist as Dr Coues. This author says of the *Limicolæ*:—"With a few exceptions the wing is long, thin, flat, and pointed, with narrow, stiff primaries, rapidly graduated from 1st to 10th; secondaries in turn rapidly lengthening from without inward, the posterior border of the wing thus showing two salient points separated by a deep emargination. The tail, never long, is commonly quite short, and has from 12 (the usual number) up to 20 or even 26 feathers (in one remarkable group of snipe). The legs are commonly lengthened, sometimes extremely so; rarely quite short, and are usually slender; they are indifferently scutellate or reticulate, or both. The feathers rarely reach the suffrago. The toes are short (as compared with the case of Herons and Rails of the next group), the anterior usually semi-palmate, frequently cleft to the base, only palmate in *Recurvirostra* and only lobate in *Phalaropodidæ*. The hinder toe is always short and elevated, or absent. The length of the phalanges of the anterior toes decreases from the basal to the penultimate. The lower part of the crus never has feathers inserted upon it, though the leg may *appear* feathered to the suffrago, owing to the length of the feathers. The bill varies much in length and contour, but is almost always slender, contracted from the frontal region of the skull, and is as long as, or much longer than, the head, representing the 'pressirostral' (pluvialine) and 'longirostral' (scolopacine) types. Furthermore, it is generally in large part, if not entirely, covered with softish skin, often membranous and sensitive to the very tip, and only rarely hard throughout. The nostril is generally a slit in the membranous part, and probably never feathered."¹

The special characters as confined to the curlews are—their

¹ *Key to North American Birds*; 2nd edition, by Elliott Coues. Boston, 1884, p. 596.

long, extremely sensitive, downward-curved bill; their tarsi with only very slight scutillations; their toes all present, and showing a slight basal web.

Of the Skull.—It was originally my intention to present the reader with a classified list of the material I have on hand to compare my skeletons of *Numenius* with; but, upon examination, I find there is so much of it, that such a list will be omitted. The collections of the Smithsonian Institution and Army Medical Museum are at my command, and they contain much of value that I will take pleasure in referring to as we proceed, simply calling attention to the specimen, either by footnote or in parenthesis, as convenience may suggest. It gives me pleasure to thank, in addition, however, Mr F. A. Lucas, of the former institution, for the loan of three valuable skulls—one each of *N. arquata*, *N. phaeopus*, and *Limosa rufa*, all taken from specimens of these birds collected in France.

Curlews are all the very types of that class of birds which the late Professor A. H. Garrod, F.R.S., designated "Schizorhinæ." In them "the posterior margin of the osseous nares has a distinctly slit-like or triangular form, instead of being simply concave."¹

This character is seen in my drawing of the superior aspect of the skull of *N. longirostris* (Plate V. fig. 1, B, n), and precisely the same condition exists in the skulls of all the other species of this genus that I have examined. Not having in my possession the young of any curlew, it will be impossible to exactly define the limits of the nasal bone. In the adult of the long-billed curlew, as well as the other species, the determinable part of this bone consists in a slender osseous rod with dilated extremities, extending from the fore part of the skull obliquely downwards and forwards to a point where the palatine and maxillary unite. The manner in which this is done may be seen in the figure last referred to. The *premaxillary* is quite broad and subcompressed as it slopes somewhat gently away from the frontal region of the skull, between the nasal bones. It becomes gradually narrower as it proceeds towards the distal tip, but alters but little in form. In an old adult *N. longirostris*, it is nearly six times as long as the remainder of the skull,

¹ "On the Value in Classification of a Peculiarity in the Anterior Margin of the Nasal Bones in certain Birds," *Proc. Zool. Soc.*, 1883, pp. 33-38.

twice as long as the corresponding parts in *N. borealis*. Other forms graduate between these two; in *N. arquata* it is fully four times as long, and is more generally curved throughout.

At the point marked *i* in Plate IV. fig. 3, and in *b* of Plate V. fig. 1, the nasal meets the maxillary. Beneath, and a little beyond this point, the palatine also merges with these bones. These elements thus unite to form a common rod that contracts immediately after the union to a delicately-fashioned stem that I have given the name of the subnarinal bar. They are seen on either side of the premaxillary, at first beneath the osseous narinal slit, then to pass under this bone, becoming at the same time flatter, more closely applied for the entire length, until they merge into it near the tip at *k* (Plate IV. fig. 3). In *N. longirostris* these bones may be pulled away from the premaxillary, as shown by the dotted lines in Plate V. fig. 1, *A*, and they spring back to their original position when the hold is released. This is only possible in those curlews that have very long bills. It is not particularly a noticeable feature in the Eskimo curlew, nor the whimbrel. As I am not so fortunate as to have at hand the skeleton of the young of the sickle-bill, it becomes impossible to determine the exact part the nasal, maxillary, and palatine take in forming this subnarinal bar. The sutures are completely obliterated in the adult skull. Much less is it possible to tell the precise limits of the nasal bone at its superior extremity. It may have to do with the median crest of bone found beneath the premaxillary and closely applied to it and to the entire anterior border of the ethmoid, from which it seemingly is developed. Or perhaps the delicate curling crest of bone found just within the nasal bar above, and united with the rounded outer margin of the premaxillary, may have to do with it. This latter seems quite probable, and indistinct sutures seem to point to this latter conclusion.

In *N. hudsonicus* this latter feature is absent, while, on the other hand, it is exaggerated in *N. borealis*, in which bird the entire rhinal chamber seems to be filled with this enlarged, here, a hollow sub-cylinder of thin bone, that meets a similar cylindrical formation of the maxillo-palatine coming from below (compare *c* and *d*, Plate V. fig. 2). The median plate, referred to above, is present in all the curlews. We find the *vomer* to be

a very well developed bone in *N. longirostris*. The anterior portion, beyond the rostrum, is a thin osseous plate, placed horizontally and shaped like an arrow-head, with the broad part behind. On the under side there is a thin vertical median crest, that in front merges into the free pointed extremity, while posteriorly it is produced backwards by two vertical plates that grasp the rostrum. These at their hinder ends meet the palatines on either side to anchylose with them.

The anterior extremity of the vomer in *N. hudsonicus* and *N. phaeopus* is decidedly forked, otherwise the description just rendered will answer very well for the other forms we have under examination. With the exception to what I have already said in regard to the maxillo-palatine for *N. borealis*, this bone has, on either side, a like character in the remaining forms, including *N. arquata*. It is developed as an extremely delicate lamina of bone from the inner margin of each palatine. Anteriorly it merges into the naso-maxillary junction. Externally this plate looks downwards and outwards, and is pierced by at least two, the usual number, large oval foramina. The vomer passes between these plates and never touches them; it may be in contact, however, in *N. borealis*. Upon their inferior aspects, each palatine presents, for the most part, two descending plates, an inner and an outer one, forming a longitudinal concavity between them. Anteriorly, a palatine becomes thicker horizontally compressed, and turns outward to merge into the subnasal bar, as already described. Posteriorly they support each a pterygoid head, that is directed outward to articulate with the pterygoid. Their superior surfaces are convex, and each one develops an ascending plate for its inner margin, near the middle, that is carried backwards to its union with the vomer, and forwards to the commencement of the maxillo-palatine lamina. Owing to the comparative greater length of skull in *N. hudsonicus* and *N. phaeopus*, these bones are longer in these species. In fact, they are shorter in our long-billed curlew than in any other in proportion to its size. A *lacrymal*, though small, stands out quite prominently at the antero-superior orbital border. It articulates largely with the nasal, and in all curlews sends down a slender bony style that unites with the upper and outer angle of the ethmoidal wing, by which means a large

foramen in this locality is encircled. These ethmoidal wings have the same general appearance in all the members of the genus. Each one is a quadrilateral plate, projecting nearly at right angles from the mesethmoid, to form quite an ample partition between the rhinal and orbital cavities.

The interorbital septum is never entire in any of the true curlews, but is pierced in almost identically the same manner in every species. The forms of these interorbital vacuities can best be seen by referring to the several lateral views of the skulls accompanying this paper. But one specimen of the skull of *N. hudsonicus* lies before me, and in that the dividing bar between the two openings is evidently broken out. I have restored it by dotted lines (Plate V. fig. 2, c). The *pterygoids* are comparatively short bones in all the curlews, more particularly so in our present subject. They are twisted and angular in appearance, with sharp longitudinal edges. An elliptical facet occupies the middle of the inner aspect of each, that articulates with the basisphenoid process on either side.

Each *quadrate bone* presents the usual undulatory surface, upon its mandibular head, for articulation with the lower jaw. Just above this, on the inner aspect, is a small semiglobular facet for the cup on the outer end of the pterygoid. The orbital process is a quadrate, lamelliform plate with truncate extremity, while two articulating facets are seen to occupy the dilated end of the mastoid process of this bone. On the outer side we find the usual cotyle for the projection on the quadrato-jugal. The form of the quadrate varies but very little among the other representatives of this genus. Several foramina are seen at the base of the deep sunken cavity, from which the fifth pair of nerves issue. This is the case in all the species, and this elliptical pit on the posterior wall of the orbit, just above the quadrate, is quite a striking feature of the skull. Ossification is so far deficient in the interorbital septum opposite the exit for the optic nerves, that this aperture is here one large circular opening. To its outer side, however, separate and minute circular foramina exist for the third pair. This latter condition seem to be common to all the species. The olfactory nerves, in the anterior part of each orbit, has for its reception a well-marked canal, that leads to a foramen (*N. longirostris*), or a notch (*N. phaeopus*), into the rhinal chamber.

A side view of the skull presents for examination, in addition to other points already described, the osseous entrance to the ear, which is here shielded behind by a rather prominent tympanic wing. The sphenotic process in all curlews, except *N. borealis*, is a long, sharp-pointed spine, and even in the exception it may become quite long in old birds.

An upper and lower spine project forward from the squamosal, over the articulation for the quadrate. This feature is more prominent in *N. arquata* of the Continent than any of our American forms, though it is quite a striking character in the lateral aspect of the skull in *N. longirostris*.

In the eye the usual sclerotal plates are found; they are small, comparatively, and about twenty in number. The superior aspect of the skulls of these birds offer some very diverse characters. In all the fronto-maxillary region is concave, and traversed by a longitudinal groove that dies away beyond on the premaxilla. This groove is deepest in *N. arquata*. In *N. longirostris* the superior orbital peripheries are but slightly serrated, and the orbital roof just within them is pierced, but by a very few minute foramina. The "glandular depressions" are shallow. The surface between them is depressed, and a double raised line is observed, that in each case is a part of the raised semilunar boundary to the glandular depressions in question. In *N. phaeopus* the raised lines have merged into a single median one; the orbital rims are decidedly serrated with small foraminal perforations, and the glandular depressions would hardly attract attention. The raised median line is single and still more prominent in *N. arquata*, causing the depressions to be more concave. In my specimen one large foramen is seen close to the orbital rim on one side, situated rather posteriorly, with a corresponding notch on the opposite side. In *N. hudsonicus* the orbital rims are comparatively smooth; no evidences exist of the glandular depression, and the region is barely concave; a minute foramen exists on each side posteriorly. *Numenius borealis* has strongly marked glandular depressions of a semilunar form, situated just within the smooth orbital peripheries. A decided median groove divides them longitudinally, which in this bird is continuous with the groove described in the fronto-maxillary region. The glandular depressions terminate ante-

riorly in this curlew, in a notch, on either side, just behind the lacrymal bones. The parietal region is smooth and globular, being impressed in most of the species by a longitudinal median groove, most noticeable in *N. arquata*, less so in *N. borealis*, least of all in *N. phaeopus*. Among the chief points of interest in the basal view is the form of the foramen magnum. This is nearly circular in *N. longirostris* and *N. arquata*; cordate in *N. phaeopus*.

The condyle is small and hemispherical in all the species, and has situated beyond and on either side of it, the usual vascular and nervous foramina seen in this locality in ordinary birds' skulls.

Two large supraoccipital foramina, of elliptical outline, exist in our present subject and in *N. arquata*; these openings are very small in the whimbrel, and exist only on one side in *N. borealis*, as a minute perforation.

The surrounding muscular line of the occiput is quite strongly marked in all the species; least of all in the Eskimo curlew.

Within the brain-case we find the tentorial ridges quite prominent, well dividing the various encephalic compartments. The longitudinal one appears to be ungrooved by the sinus.

Foraminal openings occur in the usual localities for the entrance or exit of nerves and vessels. But little diploë tissue seems to be deposited between the tabular walls of the cranial vault, these latter being quite thin, and composed of firm compact bone.

The curvature of the *mandible* is almost identical with that of the upper bill or premaxillary. When articulated with the skull, it is found to be in all the species a few millimetres shorter than the latter bone. In *N. longirostris* the rami separate and diverge from each other at a point about midway between tip and articular extremity. Beyond this point the mandible is in one piece, rounded beneath and with rounded lateral angles above. A groove deeply marks the bone along its entire course in this portion, in the median line. The rami still remain rounded for some distance backwards after they separate from each other, but, just before they arrive at the long slit-like ramal vacuity, they dilate to become lamelliform plates compressed from side to side. The upper borders of these

plates curve inwards towards each other. A second small circular foramen, situated at the base of a larger concavity, on the outer aspect of the ramus, between the vacuity and the hinder end, exists in all the specimens before me, except *N. hudsonicus*. The articular ends are of a form most common to the class; they are produced posteriorly into small vertical plates, that turn outwards, but do not curve upwards to any great extent, as we find them in the *Gallinæ*.

At the inner tip of each we find the usual pneumatic foramen. The sutures designating the limits of the bones that originally entered into the composition of the mandible in any of this genus, have been almost entirely obliterated, the edge of the dentary sometimes being persistent.

With the exception that the cerato-hyals have coalesced with the glosso-hyal, or the posterior part of it, as is usual among birds, all the remaining elements of the *hyobranchial apparatus* of the curlew remain free during life. The first piece of the arch, just referred to, has the form of a long arrow-head, with quite a sizeable fenestra towards its hinder end. The first basi-branchial has a median longitudinal ridge above, connecting the two enlarged articulating extremities; the posterior one has two facets for a cerato-branchial element on each side. These are long and slender, curving upwards. They support the equally delicate epi-branchials, which terminate in filaments of cartilage.

The second basi-branchial is quite short comparatively, it being in turn produced backwards by a slender cartilaginous tip.

Among interesting comparisons to be noted with other American limicoline forms, in so far as the skull is concerned, we find in *Tringoides macularius*, that the glandular depressions on the roofs of the orbits are long and narrow, and bound the entire supraorbital periphery. A deep depression occurs in the fronto-maxillary region of this sandpiper, and the vomer is very slender, being pointed anteriorly. The supraoccipital foramina are present, and of some considerable size. Very large vacuities occur in the interorbital septum, and the foramina for the optic, olfactory, and other nerves, have all run together.

Batramia longicauda does not possess the supraoccipital

foramina, and the glandular depressions above the orbit are still narrower than we found them in *Tringoides*. The wing of the ethmoid on either side has a spur on its outer margin, directed forwards in this tattler. In *Totanus melanoleucus* the glandular depressions are wider again, and the supraoccipital foramina are present. A median notch is found in the upper border of the foramen magnum. In *Totanus flavipes* nearly half the anterior wall of the brain-case is deficient, and the inter-orbital septum is very large. This latter character does not occur in the willet (*Symphemia semipalmata*). In this interesting bird we find the supraoccipital foramina to be of some size, and of an elliptical outline. The glandular depressions are barely perceptible. Just beyond the fronto-maxillary region, on the culmen, we note the persistence of the premaxillary sutures. This shows to some extent how far the nasals must extend forwards. The vomer is pointed anteriorly, and the inter-orbital septum is divided by an osseous bar. Upon a basal view, we find that the lower borders of the maxillo-palatine plates appear. They are attached to the palatines anteriorly, being directed backwards as free lamina. Their connection anteriorly with the maxillaries is by their outer angles. In the mandible of *Symphemia* the true ramal vacuity has become a mere slit, filled in with a plate of bone; while the small foramen I described in the curlews is here very large, and almost entirely usurped its place.

This condition likewise exists in *Limosa fæda*. The rims of the orbits in this bird are rounded, differing in this respect from the curlews. In this godwit, too, we note a pointed vomer in front, and the presence of the supraoccipital foramina on the occiput. The glandular depressions above the orbits have disappeared, and the openings in the interorbital septum are three in number, and smaller. A deep, circumscribed, and obliquely-inclined groove is found on the lateral aspect of the skull, back of the ear-entrance. In *Limosa rufa* a deep gutter is seen between the orbits on a superior aspect of the skull. Anteriorly it is bounded by an eminence on the premaxillary. The lacrymal is small in all the godwits, and connects with the alæ-ethmoid, as in the curlews.

Most noticeable in *Tringa* is the absence of the glandular

depressions, and the extreme narrowness of the region of skull where they occur in the other forms. *Tringa bonapartii* (No. 1631, Army Med. Mus. Collection) has the supraoccipital foramen, and the fenestra in the interorbital septum, as in the curlews. There seems to be in the mandible an inclination for the hinder ends to bend downwards.

This character is also observable in *Actodromus minutilla*, and in this sandpiper space between the orbital margins, on the superior aspect of the skull, is reduced to a very narrow isthmus. It is much wider, comparatively, in *Actodromus bairdi*; and this form also faintly shows the glandular depressions. They are quite well marked behind. The mandible shows the posterior bend, and the articular extremities throw off behind lamelliform, upturned processes, that are a prominent feature in this bone. The vomer is pointed in front, and the supraoccipital foramina are present.

Actodromus maculata and *Pelidna alpina americana* possess skulls very much alike in many of their characters—in the arrangement of the maxillo-palatines, the presence in each of the glandular depressions, with a similar form. Both have the supraoccipital foramina, and great deficiency of bone in the anterior wall of the brain-case and interorbital septum. They differ in the form of the ethmoidal wings. *A. maculata* shows a little bony loop, projecting forwards from the outer border of this plate, which is absent in the dunlin. In the pectoral sandpiper this ethmoidal plate is not carried up so far as it is in *Pelidna*, in which bird it absorbs the lacrymal on either side.

The little osseous loop on the ala-ethmoid, referred to as a character in *A. maculata*, is seen also in *Rhyacophilus solitarius*. Here, however, its upper limb comes down from the lacrymal, to throw in its lower limb at a right angle to the ethmoid. This explains the manner in which it is developed, and accounts for its presence. The vomer is pointed anteriorly in the solitary tattler. A deep median pit characterises the fronto-maxillary space in *Ereunetes pusillus*.

As we pass from the genera we have just been considering to the genus *Gallinago*, we are at once confronted by a widely different, though none the less interesting, series of characters in the skull. Indeed, so diverse is the plan upon which these

birds' heads are built, that I believe the drawings that I have made to accompany this paper will not come amiss in conveying an idea of their structure. My choice has been the skulls of *Gallinago*, *Philohela*, and *Himantopus*, though many others equally engaging might be added.

The greater part of the brain-case in *Philohela* and *Gallinago wilsoni* occupies a position at the base of the cranium. This brings the foramen magnum into the horizontal plane, and crowds other parts of the skull to the front, as shown in the cut. Although the supraoccipital prominence is but slightly elevated, it shows the usual elliptical foramina noticed in many other species and genera.

A wide median groove is found along the skull on the superior aspect in *Gallinago*, which is shallower in *Philohela*, although in this latter bird the orbital rims are more elevated.

A true septum narium exists in both of these birds, being most complete in the snipe. The large lacrymal sweeps backwards to join with the post-frontal, thus completing the orbital periphery with bone, a very rare condition in birds. In *Gallinago*, and in the woodcock too, the interorbital septum is quite complete, though in the former bird many small deficiencies occur in the bone on the anterior wall of the brain-case. The pterygoids in *Philohela* are exceedingly short and thick, the facet for the basi-sphenoidal process occupying nearly the entire length of the shaft.

In the mandible of the snipe and woodcock the hinder end is bent down almost at a right angle, and the ramal vacuity is unusually large in *Gallinago*.

Himantopus shows an entirely different form of skull, as we may see by its comparison in the figures. Viewed superiorly, we find the median crease very deep between the orbits, and the glandular depressions on either side of it are semilunar in form, strongly stamped, definite in outline. Each terminates anteriorly in a single foramen, that pierces the roof of the orbit beside the lacrymal bone.

The interorbital septum in the black-necked stilt is markedly deficient, and the anterior wall of the cranium does not fare much better in this respect. Supraoccipital foramen of the most usual form are found in this bird also, the muscular lines

of the occiput being well defined above them. The ethmoidal wings are but feebly developed, and the descending spine of the lacrymal on either side falls far short of reaching this bony projection. Upon basal view we find the palatines long and narrow, with the vomer slender, and terminating in a sharp point beyond.

I should have mentioned that the most delicate vomer examined is that of the woodcock, in which bird it is drawn out to absolute hair-like dimensions. The hinder end of each articular part of the mandible in *Himantopus* has the appearance of being scooped out, so as to form a semilunarform cavity. Among all the *Limicolæ* the superficies of the cranial vault, restricted to the parietal region, is smooth and globular.

Several of the characters attributed to the skull of *Himantopus* are reproduced in *Recurvirostra americana*. Chief among these are the form assumed by the proximal ends of the mandible, the narrow ethmoidal wings, and the free-hanging ends of the lacrymals, though the main part of these bones project much farther from the skull than they do in the stilt. The avocet differs from *Himantopus* in having a more perfect interorbital septum, in the supraoccipital foramina being circular, in the vomer being broad and widely forked at its expanded anterior extremity, in the shallower glandular depressions, which in the avocet merge together in the median line, and are carried out on the projecting lacrymals. It is scarcely necessary to call attention to the vast difference in the form of the skeleton of the bills in these two birds. The avocet stands alone with his upturned mandibles, and even the beak of the stilt is quite unique.

Phalaropes have a very deficient interorbital septum; this is particularly the case in *Lobipes hyperboreus*, in which bird it may almost be said that it lacks any bony partition between the orbits or wall to the adjoining cranium. Wilson's phalarope (*Steganopus wilsoni*) is somewhat better off in this respect. In these birds, the margin of the foramen magnum is notched mesially and above; and as in all the limicoline birds, the pterygoids articulate with basi-ptyergoidal processes at the base of the cranium. Skulls of both the American oyster-catchers are before me, and a very casual study is sufficient to convince

one that they are deserving of far greater elaboration and detailed description than I will be permitted to bestow upon them on this occasion.

Anatomists will appreciate the nature of this disappointment, when I say, that not only is the complete skeleton of *Hæmatopus niger*,¹ and skulls of *H. palliatus*² at my hand, but, in addition, Kidder's type specimens³ of *Chionis minor*, that were used in his description of the structure of that bird, in his valuable paper on "Contributions to the Natural History of Kerguelen Island,"⁴ also a most perfect skeleton of *Alca torda*, presented to me several years ago by Mr Forbes.⁵ Finally to say nothing of the gulls, petrels, and gallinaceous fowls to any number.

An engaging row of skulls is facing me as I write this, and it is interesting to mark the gradual subsidence of the one character,—the supraorbital glandular depression, powerfully sculpt in the skull of *Alca*, and riddled with foramina (a very large one on either side, anteriorly). Far more feebly impressed in *Larus*; remaining about the same in *Hæmatopus niger*; to be shallower still in *H. palliatus*; all of the latter three having the perforating foramina small, and less and less numerous. Then we ascend to *N. longirostris*, where it is still evident, less so in *N. arquata*, to finally become obsolete in *N. hudsonicus*. And what are we to say for its significance in *Himantopus*? So very marked, and with the single *anterior* foramen (see *Larus*) still persistent.

What we have said of these depressions applies with equal force to the crotaphite fossæ—though a longer series would show this better, as this feature has died out before reaching the oyster-catchers. The lacrymals are very prominent in these latter named birds, and from a superior view simulate the *Laridæ*, while its connections below with the ethmoidal wings are very much the same as in *N. borealis*, or *longirostris* as for

¹ No. 13636, Collection in the Smithsonian Institution.

² Two specimens in the Army Medical Museum.

³ Now in the collection at the Smithsonian Institution.

⁴ *Bulletin of the United States National Museum*, No. 3, 1876, by J. H. Kidder, M.D. (at that time) Passed Assistant-Surgeon, United States Navy.

⁵ Mr W. A. Forbes, Prosector to the Zoological Society of London, an anatomist of great promise. Since died at the post of honour, on a scientific exploration, at Shonga, Africa.

that matter. Yet, on the other hand, but *very little* trimming would be necessary to convert the lacrymal of a curlew into that of a grouse. Again, the connections of the descending process of this bone in *Larus delawarensis* is *precisely* as I described it for *Phyacophilus solitarius*, only, of course, upon a large scale, the subject itself being so much larger.

I find in *Hæmotopus niger* the occipital prominence much elevated, but unpierced by the foramen described for other forms. The vomer, bifid behind, is carried far beyond the maxillo-palatines, to be forked at its tip. But one fenestra occurs in the interorbital septum, while the foramina for the exit of nerves from the brain-case are distinct for each pair.

Of the Vertebral Column.—There are fifteen vertebræ in the cervical portion of the column of *N. longirostris*. The only other complete skeleton I have of a curlew (*N. borealis*) shows the same number, so we may pretty safely predict that this count will hold good for the genus. Ribs are found free upon the two ultimate vertebræ, and in my specimen of the long-billed curlew, the thirteenth vertebra shows persistent sutures, upon the lines of ankylosis of the pleurapophyses on either side. So examples may be found where the thirteenth, fourteenth, and fifteenth, or last cervical may all possess free ribs. In the atlas, the neural arch is very broad from before backwards, with its posterior angles tipped with small nodules of bone. The cap for the occipital condyle is perforated by a minute foramen at its base, and just above the centre we find the neural spine of the axis, or second cervical, to be represented by a large and tuberos knob of bone, and the transverse processes in this vertebra, which are directed upwards, backwards, and outwards, are unusually stout and heavy. The "odontoid process" is small, and shows an articular facet on its inferior aspect. Beneath the hypophysis is a strong plate of bone, pointing backwards, with thickened border below.

The third vertebra, has well-developed parapophysial spines; a closed vertebral canal, elliptical foramina, one on each side, in the lamina of bone extending between the zygapophysial processes; a neural and hypapophysial spine, the former being a small plate situated posteriorly. In the fourth vertebra these characters are all still present, though the foramina above are

closed in only by an extremely slender inter-zygapophysial bar. The fifth vertebra is very much elongated; the mid portion of the centrum is represented by a median longitudinal lamina of bone, extending between the more solid and terminal pieces that support on their outer aspects the articular facets for the vertebræ before and behind it. The neural spine is reduced to a sharp line; the posterior zygapophyses are outstanding processes. The sixth, seventh, eighth, and ninth vertebræ are substantially the same in character as the fifth, though they are growing shorter as we proceed backwards. They show also the open carotid canal. In the tenth vertebra this is replaced again by a hypapophysis, a single plate placed anteriorly in the centrum beneath. The vertebral canal is still a closed passage, and the neural spine is absent. Extensive pneumatic foramina exist in all the ultimate segments of the cervical division of the spinal column. The eleventh and twelfth vertebræ are slowly changing, to bring about what we find strongly developed in the thirteenth. In this latter we observe a well-pronounced *double* neural spine, occupying a mid position on the neural arch. The post-zygapophyses are elevated, but still project outwards. Anteriorly the vertebra is very broad from side to side, owing to the far-spreading transverse processes, that here overarch the vertebral canal, that is closed in beneath by the anchylosed ribs, already alluded to above as being a character of this vertebra. The lateral aspects of the centrum show a deep elliptical pit on each side, with numerous circular pneumatic perforations at their bases. The hypapophysis is a single plate, occupying the mid portion of the centrum. In the fourteenth vertebra, the ribs, or rather the delicate pleurapophyses, have been liberated; the hæmal spine exhibits evidences of becoming tricornuate; the neural spine stands well above the vertebra, as a tuberos and solid mass, bearing sharp spines, directed backwards upon its outer and posterior angles. These are the continuations of the lateral raised rims of the neural spine proper, and they project also somewhat anteriorly. This is one of the most prominent features of the fifteenth or last cervical vertebra; it is explained, however, in the dorsal series, by its evolution into the ordinary quadrate dorsal neural spine, with the forked extremities of the limiting rim at their crests. The hæmal spine

of the fifteenth vertebra is triplicated, having three plates, though they are not particularly prominent. In it, too, the free ribs are quite long, and are without uncinatæ processes.

Numenius borealis shows but few structural departures in its cervical vertebræ from those I have just described for *N. longirostris*. The cap of the atlas does not seem to be perforated at its base; the pleurapophyses of the thirteenth vertebra bear no striking resemblance as yet to free ribs, as they do in the long-billed curlew. The carotid canal is found traversing identically the same vertebræ in mid-neck. In both these curlews there are five vertebræ in the dorsal series, all articulating freely with each other. Above they have long osseous metapophysial filaments, that stretch for the length of one or nearly two vertebræ before and behind, in the middle of this region. The tendons have also become ossified and attached, and reach far backwards from each segment, those of the last running into the ilio-neural canals of the pelvis. The first dorsal vertebra shows two little lateral processes at the lower extremity of its hæmal spine; this plate is single and prominent in the next vertebra, but does not appear in any of the others. Each dorsal vertebra has a pair of ribs, of the most common pattern, as seen among birds. They connect with the sternum by costal ribs, and have freely articulated uncinatæ processes. These latter are very long and narrow, reaching nearly in mid-series to the second rib to their rear.

In curlews the pelvis also supports two pair of free ribs. The first pair has all the characters of the dorsals, being simply slenderer and longer. The ultimate pair are devoid of uncinatæ processes, and their hæmapophyses only articulate along the posterior borders of the pair in front of them, so do not reach the sternum. I find in my specimen of *N. borealis* an additional piece, or free costal rib, attached to the posterior border of this last pair of costal ribs again on either side.

The number and arrangement of the vertebræ and ribs of the spinal column, as far as examined, agree very nearly with *Limosa fœda* and *Recurvirostra*.

In *Himantopus* the number of cervicals and dorsals are the same as in *Numenius*, but there appear to be one pair less of sacral ribs.

The genus *Batramia* also agrees with the curlews in this respect. *Gallinago* has an additional pair of dorsals, consequently seven articulating facets on either costal border of the sternum. It seems to possess, however, but fourteen cervical vertebræ. The arrangement in the phalaropes is as it is in *Himantopus*, i.e., short of one pair of sacral ribs.

Enough has been presented, I think, to demonstrate the fact that these characters vary among the limicoline birds. I have other skeletons before me, but they have either been mutilated at the time of collection, or indifferently mounted from alcoholic specimens, making it simply impossible to gather any new facts or reliable data from them.

Of the Pelvis and Coccygeal Vertebræ (Plate IV. figs. 8, 9).—Viewing the pelvis of *Numenius longirostris* from above, we observe that the total pre-acetabular area is about equal in extent to the post-acetabular area. The ilia are long and narrow, with serrations in their anterior borders. They are pretty generally concave throughout, having a small triangular concavity, bounded by a raised rim, immediately in front of each cotyloid ring. About their anterior thirds they closely grasp the common neural spine of the sacrum between them, thus creating closed ilio-neural canals. Posterior to the acetabula, these bones present a convex surface, being drawn out behind into prominent processes, that curve inwards. They develop outstanding bony shelves, that overhang the anterior half of each ischiadic foramen. The sacrum does not unite with the post-acetabular part of the ilia, a very marked interspace existing between them. A double row of elliptical foramina pierce this former bone, as shown in the drawing in the plate. They occur between the transverse processes of the vertebræ, and have nearly the same direction.

Upon a lateral view, the long and pointed ischium is presented to us. Posteriorly, it reaches nearly as far backwards as the pubic bone, the latter resting against its inferior edge in this locality. The pubic bone does not quite close in the obdurator foramen in any of the curlews.

Above, we find the ischiadic foramen, which in *Numenius* is very large and elliptical in outline. The relations to each other of these foramina can best be seen by a study of the figure given in the plate.

After a careful count of the vertebræ of the sacrum on the inferior or inner side of the pelvis, there seem to be fourteen. The two anterior ones throw out diapophyses to the ilia, and bear the facets for the sacral ribs. In the third vertebra these processes are extended almost directly upwards; while in the fourth and fifth, again, they are horizontal, as in the first and second. From the points where the diapophyses of the fifth meet the ilia, these bones sweep outwards, and are fashioned to enclose the basin of the pelvis. The tenth sacral vertebra throws out a strong pair of transverse processes, that have widely-dilated extremities abutting against facets, especially developed to meet them, from the ilia, immediately posterior to the acetabulum on either side.

Foramina, for the exit of the sacral nerves, are double, one being placed above the other, the increase of calibre in the neural canal for the corresponding dilatation of the cord taking place in the sacral vertebræ from the fourth to the ninth inclusive.

Although more delicately constructed, the pelvis of *N. borealis* agrees substantially in all particulars with this bone in its more powerful relative, the sickle-bill.

There are ten coccygeal vertebræ in *N. longirostris*, which count includes the triangular and rather large pygostyle.

Among others of the *Limicolæ*, the form of the pelvis is stamped with the same general characters as I have described it for *N. longirostris*. To be sure, it varies in every genera in more or fewer details; but to show these correctly, and to give any just conception of them, would require a carefully executed series of drawings, which cannot be taken up in the present connection.

The foraminal openings in the sacrum of *Gallinago*, and more especially in *Batramia*, are in a single row on each side, but unusually large. The row is double in the phalaropes, *Totanus* and *Tringoides*. In the oyster-catchers the pelvis has something more than a bare suspicion of the gallinaceous type. Its general appearance is decidedly such.

In several of the genera the number of coccygeal vertebræ ungrasped by the pelvic bones varies. The curlews, as we have just seen, possess ten, including the pygostyle. This is the case

also with *Hæmatopus* and others; but *Recurvirostra* appears to have but nine, in common with *Symphemia*, whereas a specimen of *Totanus flavipes* shows but eight. This cannot fail but be interesting if the count be constant. With the material I have at hand, however, I cannot present with safety any further facts than these here given.

Of the Shoulder Girdle (Plate IV. figs. 1, 2, and 5).—We find in *Numenius longirostris* the usual bones allotted to this arch, free, and articulated in the manner as commonly seen in the vast majority of the class. The shape of the furculum is upon the broad U-variety, and is broader in this curlew than it is in others of the same genus, and still more so than in the plovers. Viewing it laterally, we observe also that it is very decidedly curved upon itself, with the convexity directed forwards when *in situ*. When articulated, the long and pointed clavicular heads rest on either side against the inner aspects of the summits of the coracoids, while the tips extend backwards to meet the usual process furnished by each scapula. This brings the hypocleidium about opposite the middle of the anterior border of the sternum, from which it is separated by quite an interspace.

The clavicles are broader and larger at their superior or coracoidal extremities, being compressed from side to side. Above, the broad surface looks outwards; but it is gradually changed in direction as we descend to the hypocleidium, so that below it looks forwards (Plate IV. fig. 2). The hypocleidium is of a quadrate form, rather small, and has an extension of its posterior border carried up behind on the line of the median clavicular union.

In *N. borealis* (No. 12,595, Smithsonian Collection) the furculum possesses all the characters I have described for the long-billed curlew. As already intimated, however, the arch of the U is not as open, the clavicular heads are not so pointed, and the hypocleidium is nearly round in form, not being so perceptibly carried up on the clavicles at their point of meeting below. Among the plovers I find that it has the same general characteristics, and holds the same relative position when articulated to the other bones of the shoulder girdle.

In *Charadrius dominicus* the furculum is more delicately

constructed, being somewhat smaller in proportion when compared with the other bones. The hypocleidium is very small in a specimen of *Egialites vociferus* (Army Med. Mus., No. 150).

This holds good also for the avocet and the godwit, although in these birds it is a little larger in proportion, more especially in the godwit.¹ The outer aspect of the clavicular limbs above in *Gallinago wilsoni* and *Totanus flavipes* are grooved in the direction of the long axis of the bone on either side. We find this feature more or less marked also in *Tringa*. In these birds, too, the hypocleidium is formed very much as we found it in the curlews, this character being nearly aborted in *Hæmatopus*, although here the other general characters of the furculum remain the same.

The coracoid of *Numenius longirostris* is comparatively a short, thick-set bone, as scarcely any true shaft exists between its humeral and sternal extremities. Such as it is, however, is transversely elliptical on section, and occurs just below the inner process at the head of the bone. The sternal extremity is broad from side to side, in which direction it is also convex anteriorly and concave behind. Below, the sternal margin is divided into two deep concavities; the inner and broader one is completely occupied by the articular facet for the sternum. The outer is sharp and free, having attached to its upper horn a pointed and up-tilted little spine, that I will call the *costal spine* of the coracoid, it being opposite the costal border of the sternum. On the outer aspect of the bone we find the usual elliptical facet, that here forms about two-thirds of the glenoid cavity (Plate IV. fig. 5). The summit of the bone consists of a massive hooked process, directed forwards and inwards. Above and behind it is impressed by a shallow concavity, while its inner surface is devoted to an elongated facet for head of clavicle. Below this, on the inner side, we find another lamelliform process, curving inwards, upwards, and forwards, that at its tip also comes in contact with the clavicle when the bones are *in situ*. The posterior margin of this latter process is given up wholly to the scapula, which in life abuts against its entire length, as well as the shaft behind is to the glenoid cavity.

¹ *Limosa fæda* (No. 1652, Army Med. Mus. Collection) and *Recurvirostra americana* (Nos. 1596 and 1387, from the same collection).

In *Numenius borealis* the coracoid is a mere miniature of the bone we have just described for the "sickle-bill." Its costal process is, however, much less strongly marked, and would hardly attract special notice. The coracoids, as well as the other bones of the shoulder girdle, are non-pneumatic in the genus *Numenius*, and I believe generally so among the *Limicolæ*.

When articulated, the coracoids lean well forwards as they spring from their sternal beds in the curlews, while the scapulæ make angles with them of about 90°. They do not quite meet in the median line in any of the species, but are separated at this point by a thin compressed surface on top of the manubrium.

The coracoids touch each other in the median plane over the manubrial process in the genera *Recurvirostra* and *Hæmatopus*.

Symphemia semipalmata, *Totanus flavipes*, and *Bartramia longicauda* all have the costal process of the coracoid quite prominently developed; in *Limosa uropygialis* (Smithsonian Collection, No. 12,590) it is broad and quadrilateral in outline, and but slightly curved upwards.

The anterior extremity of the *scapula* in *N. longirostris* is decurved, broad, and compressed from above downwards. The blade of the bone, which is comparatively long, becomes thinner and slightly wider posteriorly, to be very obliquely truncate at the inner side of its posterior third. The angles thus formed are well rounded off, leaving this element of the shoulder girdle without any decided character attached to it (Plate IV. figs. 1 and 5, s). *N. borealis* has the hinder moiety of the scapula broader, more blade-like, the truncation more decided, and its tip in the articulated skeleton overhanging the anterior margin of the ilium. Among the plovers, and in all the phalaropes, the blade of this bone is long and narrow, being proportionately short in the black-necked stilt (*Himantopus mexicanus*). As a rule, in the *Limicolæ* it nearly always reaches back, in life, to the ilium on either side,—some forms of *Tringa* seemingly forming an exception.

Of the Sternum (Plate IV. figs. 6 and 7).—Avocets, godwits, plovers, snipes, and curlews, all being birds possessed of more or less power of flight, we naturally look for a correspondingly

well-developed sternum in one subject. In this regard we are by no means disappointed, for, taking the general size of *N. longirostris* into consideration, this bone is unusually large. The manubrium is for the most part a thin compressed median plate, with sharp edge below and thickened border above. At its base, superiorly, it is contracted again to an edge, that just keeps the coracoids apart in the articulated skeleton. The coracoidal grooves lie in the horizontal plane; they are broad from above downwards, convex at their middles, and concave at their inner and outer limits. Anteriorly the margin of the keel is very sharp, being carried clear up to the base of the manubrial process. It appears above, however, merely as a line on the front of the fortified column of bone that descends in this situation, to be gradually lost as it expands, on either side of the keel below, within this anterior margin. The carinal angle in *N. longirostris* is rounded in front, being partly covered by the raised rim that bounds the entire length of the keel below. This latter part of the sternum is exceedingly deep, being carried backwards to the very end of the sternal body by a graceful curve (Plate IV. fig. 7).

Upon the costal border we observe six transverse facets for articulation with the hæmapophyses. They are limited beyond by a low quadrate costal process—a feebly-pronounced feature in the sternum of our curlew. So high do the sides of the sternal body itself arise, that it reminds one very much of a very deep spoon, with slender processes projecting from its free border in front, corresponding to the hinder border of the sternum. These processes are four in number, two on either side, making our sternum a four-notched one. Their shape and arrangement can best be seen by referring to my drawing in the plate, where they are shown in fig. 6. On the superior aspect of the sternum, in the median line, and just within the anterior boundary, we find a deep pit, with rounded margins. At its base there seem to be a few minute pneumatic perforations. The usual muscular lines are found to be strongly marked on the sternal body and keel in this curlew, being carried back in each case nearly to its xiphoidal extremity.

The chief differences presented to us in the sternum of *N. borealis* are a greater width of the mid-process posteriorly, and a

very decided protrusion forwards of the carinal angle anteriorly. In all other respects the sternum of the Eskimo curlew seems to be the very miniature of the bone I have just described for the long-billed variety.

Professor Owen tells us that "the woodcock (*Scolopax*) has a pair of notches, with the outer boundary slender, and shorter than the broad intermediate tract; the gambets (*Totanus*), avocets, sandpipers (*Tringa*), curlews (*Numenius*), pratincoles (*Glareola*), have the four-notched sternum. In the godwits (*Limosa*, *Helias*) the medial notches are almost obsolete, and the lateral ones wide. The 'thick-knees' (*Edicnemus*) and bustards (*Otis*) have the four-notched sternum, the notches being small."¹ To this we may add that the inner pair of notches in *Limosa uropygialis*, which are very small, are smaller than they are in *L. fedea*. The inner notches disappear altogether in *Gallinago wilsoni*, although the outer pair are very deep. They are about of equal size in *Hæmatopus niger* and *H. palliatus*, while in *Totanus* the inner pair again become smaller, which is still better seen in *Tringoides macularius* (No. 862, Collection in Army Medical Museum), and less so in *Heteroscelus*, *Steganopus wilsoni*, and other phalaropes, and have a sternum very much like *N. borealis*, only much smaller in size, though no smaller in proportion for the bird. The inner notches, however, seem to be smaller. *Bartramia* shows a small pair of inner notches in the sternum, with very deep outer ones.

Actodromus minutilla and *Ercunetes pusillus* both possess four notches, as does also the black-necked stilt (*Himantopus mexicanus*). So that, of all the material that I have been able to examine, or has been available, in this great snipe-plover group—the *Limicolæ*—the only form detected with but a single pair of notches at the xiphoidal extremity of the sternum is *Gallinago wilsoni*. The sternum in this bird differs also in other respects. The carinal angle is carried far forwards; the manubrium is almost completely aborted; the anterior border of the keel is very decidedly concave; and the pectoral muscular lines on the sides of the carina are raised and rounded welts.

Of the Appendicular Skeleton—The Pectoral Limb (Plate IV. fig. 4, and Plate V. fig. 4).—It follows, as a natural consequence,

¹ *Comp. Anat. and Phys. of Vertebrates*, vol. ii. p. 26.

the members of this group all being good strong flyers, that we find the skeleton to their ample wings a thoroughly well-developed one. As a rule, with the *Limicolæ* generally, the bones entering into the brachium, antibrachium, and manus are long, straight, and of considerable calibre. From the material I have at hand, I have failed to detect a pneumatic bone in either extremity. They certainly are not so in the curlews.

The *os humero-scapulare* seems to be absent, its place being filled by ligament as in other birds where this ossicle does not appear.

The *humerus* of *Numenius longirostris* has a shaft that is much straighter than is commonly seen among birds, where it is usual to describe it as being formed like a long *f*. Its proximal extremity is comparatively widely expanded, which expansion includes the graceful canopy that arches over the site of the pneumatic orifice in forms where it occurs. A deep notch divides this from the articular facet or head for the glenoid cavity.

The "radial crest" is well developed, and bent outwards almost at a right angle with the vertical plane of the bone when in a position of rest. Should a section of mid-shaft be made, the figure would be very nearly circular; it becomes triedral, proximally and roughly elliptical towards the distal end. This latter extremity offers one point of interest,—it consists in a strong lamelliform process, projecting from the radial border of the shaft, immediately above the oblique tubercle. It appears to be a prominently developed external condyle. When the skeletal limb is closed and *in situ*, this *humeral process* overlaps the neck of the radius; or, as in *Hæmatopus*, the head of this bone, which actually articulates in a semilunar facet at its base. If my memory serves me correctly, it is intended for muscular attachment.

This process is more or less developed in all of the members of this group, at this point on the humerus, so far as I have been able to examine them. Nothing of importance attaches to the remaining points for examination at this extremity of the bone in our curlew, they simply presenting the usual form as found in the majority of the class.

Viewed from above the shaft, the *ulna* is seen to have a long,

gentle curve, extending from one end of the bone to the other, being the greatest near its proximal extremity.

The papillæ for the quill butts along the shaft are quite distinct in this bird, and still more in the oyster-catcher, where they present the unusual condition of being narrow and oblong in shape, and placed, as it were, obliquely on the shaft. To the inside of these a secondary row is seen, running down the shaft longitudinally. These little protuberances are scarcely perceptible in the phalaropes or in *Tringa*.

The *radius* of *N. longirostris* does not exhibit so much of a curve in its shaft as its companion in the antibrachium, though it is gently bent throughout its length. A concavity is scooped out of its shaft near the head, over which, I take it, tendons pass in life.

The *carpus* contains the two free bones ordinarily found there in birds articulating after the usual manner. In form these two carpal segments always remind me, the *ulnare*, of a human molar tooth from the milk set of the lower jaw, and the *radiale* of one of those chipped, irregular pebbles we sometimes see.

All of the *Limicolæ*, so far as I have seen, are endowed with a remarkably long hand. If we allow the bones of the carpus to be added to it, its length in the sickle-bill is fully equal to that of the ulna. Each bone lends its due share in proportion to produce this result, and one that strikes us at once in the articulated skeleton of the bird. The shaft of the second metacarpal is for the most part cylindrical in form, while its anchylosed companion is of very slender proportions. I find in *Numenius* and *Hæmatopus* a delicate, curved, and free joint, suspended from its distal end (Plate V. fig. 4, x).

There is an ample expanded portion springing from the posterior aspect of the first digit of second metacarpal. It is produced downwards as a flattened and peg-like process, not commonly seen. This phalanx supports below one more long and slender joint. The smaller digit of third metacarpal has a shape not unlike a compressed claw, as it hooks over the expanded portion of the finger at its side.

The Pelvic Limb.—After the process of maceration and drying, the femur of this curlew has all the appearance of a pneumatic bone, but careful search fails to discover the orifices at their

accustomed site, though a few very minute openings are to be seen on the opposite side of the bone, below the facet. This, I must believe, would be an unusual locality for such foramina. The femoral shaft in *Numenius* is straight, smooth, and cylindrical, with all muscular lines nearly obsolete. A rough surface is found on the back of the trochanterian prominence, and this portion rears well above the facet at the summit.

The pit for ligamentum teres is very shallow, and rather irregular in outline. Several of the characteristic features of the distal extremity of the bone are more keenly defined than those just described for the proximal end. The intercondyloid notch is deeply excavated; the anterior border of the external condyle is a sharp crest, while the corresponding surface on the internal one is evenly rounded. Upon the reverse aspect we find the popliteal depression well sunken, and the notch for the head of fibula cleanly cut out. A tubercle and pit exist on its outer and condyloid side for ligamentous attachment.

The length of the *tibia* in this curlew is double that of the femur, and the shaft of the bone has a general convexity inclined outwards. Sections taken through its middle third are sub-ellipses, and the expanded extremities are rather abruptly attached, more particularly the proximal one. Here the pro- and ecto-cnemial processes rise squarely from the shaft, showing but little of that tendency to merge gradually into it below. The ectocnemial process is shaped like a claw, with its point inclined downwards. Its fellow is much larger, slightly turned outwards, quadrilateral in figure, with the angles rounded off. They are produced upwards as a rotular process to a very slight extent. The fibular ridge stands out from the shaft on its outer aspect as a prominent and rather extended crest of bone.

At the distal extremity we find the inner condyle to be smaller than the opposite or outer one, as well as proportionately narrower from above downwards. In the groove between them anteriorly the tendinal bridge is ossified, the span being thrown directly across, and not obliquely, as it is in some birds. Prominent tubercles exist on either side, immediately above it, for ligamentous attachment, as an additional bridge is formed of this material at this point.

The *fibula* is compressed from side to side above, and club-

shaped. After articulating with the ridge designed for it on the tibia, it merges into the shaft of this bone a little over half-way down, measuring from the proximal extremity.

Himantopus, with its pelvic limb of twenty-nine centimetres in length, has a fibula that descends but one-fourth the distance down the tibial shaft.

The *patella* in *Numenius* is, comparatively, very small, and of an odd, irregular shape. *Hæmatopus* has the bone only represented in a diminutive cartilaginous nodule, and I am inclined to think that this sesamoid will be found missing in other limicoline birds of our fauna. It appears, though of no very great size, in the willet and avocet.

The *tarso-metatarsus* of *Numenius* is but little over a centimetre shorter than its tibia. Upon the superior surface of its proximal extremity the articular facets for the tibial condyles are deeply impressed, and a prominent tubercle arises between them on the anterior rim. Behind, the hypo-tarsus is bulky, being both grooved and pierced for the passage of the tendons. The shaft of this bone is concave longitudinally for its entire length on the anterior aspect, and less so upon the posterior. The trochlear prolongations at the distal end are large, and the extremity much expanded, a feature still more prominent in the swift-footed *Hæmatopus*.

The oyster-catcher presents us with another very interesting point in its *tarso-metatarsus*, which is very well shown in the specimen I have in my hand. It consists in the outgrowth upon the site of the usual place for articulation of the "accessory metatarsal" of a little plate of bone, placed vertically, and formed almost like a spur, with squarely truncate extremity.

Another three-toed limicoline bird, *Himantopus*, is devoid of any such protuberance on its *tarso-metatarsus*, and, as a rule, the hallux being small in so many members of the group, this bone never becomes of any size among them.

In number, the phalanges of the podal digits are arranged upon the common plan, and in no instance offer us anything beyond the well-known characteristics that pertain to the skeletal foot of a typical wader.

DESCRIPTION OF PLATES IV. AND V.

PLATE IV.

Fig. 1. Direct anterior aspect of left coracoid and scapula of *Numenius longirostris*. *s*, scapula; *c*, coracoid; life size, from a specimen taken by the author in Wyoming.

Fig. 2. The furculum of *Numenius longirostris*, from the same specimen; a three-quartering view from the right side, life size.

Fig. 3. Right lateral view of skull of *Numenius longirostris*, with mandible attached, from the same specimen, life size. *sf*, supraoccipital foramen; *q*, quadrate; *pt*, pterygoid; *j*, jugal; *pl*, palatine; *i*, points of meeting of nasal and maxillary; *h*, subnarinal bar; *k*, premaxillary; *j*, culmen; *n*, nasal; *l*, lacrymal; *eth*, ethmoidal wing.

Fig. 4. Right humerus of *Numenius longirostris*, anconal aspect, life size, from the same specimen.

Fig. 5. Lateral view of right scapula and coracoid of *N. longirostris*, life size, same specimen as the others.

Fig. 6. Inferior view of sternum of *Numenius longirostris*, life size, same specimen as above.

Fig. 7. Right lateral view of sternum of *Numenius longirostris*, life size, same specimen.

Fig. 8. Left lateral view of pelvis of *N. longirostris*, life size, from the same specimen.

Fig. 9. The pelvis of *Numenius longirostris*, viewed from above, life size, and taken from the same specimen.

PLATE V.

Fig. 1. Basal and superior views of the skull of *Numenius longirostris*, life size; *A*, the basal view, lower mandible removed; *B*, the superior view, like lettering designating like parts. *pmx*, premaxillary; *v*, vomer; *pl*, palatine; *m*, maxillary; *n*, nasal; *eth*, lateral wing of ethmoid; *l*, lacrymal; *q*, quadrate; *pt*, pterygoid; *fm*, foramen magnum; *sf*, supraoccipital foramen; also in *A*, *sn*, the subnarinal bar, and *sn'* its position in dotted lines as drawn away from the premaxillary on either side. In *B*, *i*, the point of meeting of nasal and maxillary.

Fig. 2. Right lateral views of the skulls of *Numenius hudsonicus* (*a*, the upper figure), and *N. borealis* (*b*, the lower one). Life size, from the collection at the Army Med. Mus. (Nos. 457 and 928 respectively). *pmx*, the premaxillary; *n*, the nasal; *l*, the lacrymal; *q*, the quadrate; *pl*, palatine; *a*, articular; *d*, dentary; *h*, the subnarinal bar.

Fig. 3. Left lateral views, life size, of skulls of *Philohela minor* (*E*, No. 449, Army Med. Mus. Collection), *Gallinago wilsoni* (*F*, No. 898, Army Med. Mus. Collection), and *Himantopus mexicanus* (*G*, No. 1359, Army Med. Mus. Collection). *n*, nasal; *pl*, palatine; *pt*, pterygoid; *q*, quadrate; and *a*, articular.

Fig. 4. Palmar aspect of right manus of *Numenius longirostris*, showing also distal extremities of radius and ulna, life size. *r*, radius; *u*, ulna; *s*, scaphoid (radiale); *c*, cuneiform (ulnare); *p*, pollex; *x*, claw on pollex; *i'*, index metacarpal of carpo-metacarpus; *i''*, its first or proximal phalanx; *i'''*, its distal phalanx; *m'*, medius metacarpal of carpo-metacarpus; *m''*, its digit. Limb from the same specimen that furnished the drawings for the plate.

Fig. 5. Parts of right pelvic limb of *Numenius longirostris*, life size. *tm*, anterior view of the tarso-metatarsus; *tm'*, a view of the surface of its proximal extremity at right angles to the shaft; *hp*, the hypo-tarsus; *tm''*, a view of the surfaces of the distal extremity of tarso-metatarsus at right angles to the shaft, showing the trochleæ for the podal digits; *T*, upper extremity of the tibia; *T'*, view of its proximal surface at right angles to the shaft; *F*, anterior aspect of the femur.

THE ANATOMY OF ACQUIRED FLAT-FOOT. BY J.
SYMINGTON, M.B., F.R.C.S.E., *Lecturer on Anatomy, Edinburgh.* (PLATE VI.)

THE anatomy of this comparatively common deformity does not appear to have received much attention in this country. Nearly half a century ago, it was considered by a writer in Todd's *Cyclopædia of Anatomy and Physiology* as probably due to a relaxation of the inferior calcaneo-scapoid ligament, but he admits that he had no opportunity of dissecting a specimen, his ideas on its anatomy being derived from a careful examination on the living body. The account of flat-foot given in Holme's *System of Surgery*, 3rd edition, 1883, by such a well-known authority on Orthopædic Surgery as Dr W. J. Little, contains no anatomical details but what can be ascertained by external examination. Almost all the other English articles on this subject possess a similarly purely clinical basis. This may be attributed to the absence of specimens, the distortion, though common, not being fatal or requiring amputation. So far as I have been able to ascertain, there are no preparations of flat-foot in any of the following museums:—Hunterian, St Bartholomew's, University College, London Hospital, St Thomas', Guy's, Edinburgh University, and Royal College of Surgeons, Edinburgh. In fact, I have not been able to hear of a specimen in any of our museums.

Two valuable contributions, founded upon a careful examination of dissections, have however been made to this subject by C. Hueter¹ and G. Hermann von Meyer.²

By Hueter its anatomy is treated partly from a developmental point of view. He gives an excellent account of the position and shape of the tarsus in the newly-born child. The foot is then supinated, but as soon as the child begins to walk it becomes pronated. This prone position is followed by certain changes in the tarsal bones, especially in the os calcis, astragalus, and scaphoid. As a consequence of the altered position

¹ *Grundriss der Chirurgie*, Von Dr C. Hueter, ii. Hälfte, 1882.

² *Ursache und Mechanismus der Entstehung des erworbenen Plattfusses*, 1888.

of the bones, certain surfaces are subject to increased pressure and atrophy, while others relieved of pressure, grow. Flat-foot he regards as an over-pronation of the foot, and the changes in the tarsal bones are to be explained by the effects of alteration in pressure. The bones specially involved are the three mentioned above. He considers that there is a general relaxation of the ligaments of the foot, but he refers specially to the inferior calcaneo-scaphoid ligament, the surface of which, he says, presents a marked increase.

Dr G. Hermann von Meyer, in his monograph, endeavours to disprove the current view, that in consequence of the relaxation of the inferior calcaneo-scaphoid ligament, the head of the astragalus is displaced downwards. He maintains that there is no elongation of the above-mentioned ligament, and also that the inner border of the foot is not increased in length. The most important part of his paper, which will be considered subsequently, is that in which he describes the mechanism of displacement of the astragalus in relation to the rest of the tarsal bones.

During last winter session I met with an adult male subject in my practical anatomy rooms, in whom both feet presented the appearances typical of advanced flat-foot. He was a big, heavy man, six feet in height, but the muscles of the body generally were soft and flabby. There were no indications of his having suffered from rickets. After the muscles of the leg had been dissected, the feet were removed by amputating a few inches above the ankle, and kept for special examination. A plaster-of-Paris cast was taken of the left foot. The right foot was frozen, and several sections were made of it, while the left foot was dissected in the usual way. The deformity was slightly more marked in the left foot than in the right, but in both the arch could be restored by manipulation, but could not be maintained without artificial support, the weight of the body being sufficient to reproduce the deformity. From external examination there appeared to be abnormal mobility in all the tarsal joints.

As previously mentioned, Meyer maintains that the inner border of the foot is not increased in length in flat-foot. He endeavours to prove this, not merely by the mode of displace-

ment of the bones, but by actual measurements. He measured five flat feet and six normal ones. The average of the inner borders of the flat feet equalled those of the normal feet, but the outer borders of the former averaged 1 cm. less than the latter. From this he concludes that there is no increase in the inner border, but that the outer border is diminished. There is an obvious fallacy here, for the facts given can be equally, and, I believe, more correctly, explained on the supposition that the normal feet selected were larger than the flat ones. This would account for the greater length of the outer borders of the normal feet, and the equality in the inner borders of the two sets may be attributed to an elongation in the flat-foot specimens. As both feet, in my case, were involved, they cannot be used for comparison; but there is another method by which this point can be determined.

In a paper¹ by Mr C. Hilton Golding-Bird, it is stated that the middle of the inner border of the foot corresponds normally to the first cuneo-metatarsal joint. The inner arch of the foot only extends as far forwards as the head of the first metatarsal bone, so that the greater part of the arch is in the posterior half. If the arch be flattened the posterior half will be more increased by the change than the anterior. Mr Golding-Bird measured a number of cases in the living body, and often found the posterior measurement to exceed the anterior by $\frac{1}{2}$ to $\frac{3}{4}$ of an inch. I have found this guide to the middle of the inner border of the foot to be a tolerably exact one. I examined nine feet very carefully in the dissecting-room, and found that in three of them the anterior and posterior measurements were equal, in two the posterior excess was .5 cm., in one .75 cm., and in the remaining three, 1 cm. In the left foot in my possession, the excess of the posterior segment over the anterior was 2 cm. Although the increase in length of the inner border is not so great as it would be were the arch flattened simply by extension in a longitudinal direction, there is still some increase in length. The muscles of the left foot were carefully dissected, but no peculiarity was observed, other than that the short muscles on the inner part of the sole of the foot were atrophied,

¹ "Pes valgus acquisitus, Pes pronatus acquisitus, Pes cavus," *Guy's Hospital Reports*, vol. xli., 1883.

and had undergone partial fatty degeneration. This was probably secondary, the result of the pressure of the flattened arch. Professor Sayre (*Orthopædic Surgery*, p. 62) attributes a very important action in the maintenance of the inner arch of the foot to the *tibialis anticus*, and he gives its partial or complete paralysis as the cause of flat-foot. I could detect no special change in this muscle in either limb. Mr Golding-Bird says that he has failed to find the atrophy of this muscle described by Sayre in any of his cases,—50 in number,—although he methodically looked for it. The *peronei* muscles were not contracted; but their synovial sheath communicated with the ankle-joint by an opening in the capsule, which readily admitted the index finger.

Ankle-Joint.—The ligaments of this joint were so lax, that before any of them were divided, the tibia could be raised nearly three-quarters of an inch above the astragalus, and the finger could be easily passed through the opening in the capsule already mentioned, between the tibia and astragalus. The only ligament requiring particular notice was the external. Its three fasciculi were not so well defined as usual; the middle one was nearly horizontal, inclining from the *os calcis* forwards to the fibula. The posterior fasciculus was very rudimentary, its middle and outer parts being almost worn away by the pressure of the fibula against the *os calcis*. The ligaments of the ankle-joint were divided in order to see the interior of the joint. The normal articular surfaces presented no marked alterations, but additional ones had been produced by the contact of the fibula with the *os calcis*. The surfaces of these facets were formed by compact osseous tissue. There was a facet on the lower end of the fibula between the depression on its inner surface, and the groove on its posterior surface for the *peronei* muscles. It was three-quarters of an inch long, and three-eighths of an inch in breadth. Another facet, smaller in size, was found close to the apex of the malleolus. These two facets articulated with two others on the outer surface of the *os calcis* (see Plate VI.). The external calcaneo-astragaloid ligament was destroyed, and the synovial cavity of the ankle-joint was continuous with that of the posterior calcaneo-astragaloid, and also with the cavity between the abnormal articulations of the fibula and *os calcis*. Both Meyer and Hueter mention

the articulation of the fibula and os calcis as always occurring in cases of advanced flat-foot.

The conditions of the ankle are of interest to the surgeon in connection with Professor A. Ogston's operation.¹

After the examination of the ankle, and before any of the ligaments of the tarsus proper had been divided, the position of the astragalus in relation to the rest of the tarsus was determined. It is at the talo-tarsal joints that the deformity commences, and it is there that the displacements occur that constitute its most important features.

G. H. von Meyer devotes special attention to the mechanism of the movements of the astragalus. When the sole of the foot is placed upon the ground, and pressure exerted upon the astragalus from above, its body glides forwards upon the os calcis, while the head of the bone sinks downwards and inwards. This movement is described by Von Meyer as occurring round an oblique axis passing from the inner side of the upper surface of the neck of the astragalus to the middle of the lower border of the posterior surface of the os calcis. He shows that the outer border of the trochlear or superior articular surface of the astragalus moves forwards and downwards, while its inner border will perform a smaller movement in the opposite direction. As a consequence of this, the axis of the trochlear surface will incline more inwards—nearer the big toe. By the same movement the trochlear surface will acquire an inclination outwards, for, as we have seen, the outer border moves down, and the inner up. The transverse axis of the trochlear surface, which we may represent by a line connecting its outer and inner borders, must, however, on account of its connection with the bones of the leg, maintain its parallelism with the base. It does this by causing a valgus position of the rest of the tarsus. By an excess of its normal movement, the astragalus becomes displaced towards the inner side of the rest of the foot. An excellent method of representing this has been devised by Von Meyer. He indicates the sole of the foot by a triangle made by uniting three points, viz., the centre of the heel, and the heads of the 1st and 5th metatarsal bones. This triangle, marked *abc*, is drawn in Plate VI. fig. 1; but instead of the

¹ "On Flat-Foot and its Cure by Operation," *Lancet*, 26th January 1884.

middle of the posterior surface of the os calcis, I have taken the posterior point of support, viz., the internal tubercle of the os calcis. Instead of the whole of the astragalus being indicated it is represented by a point. This astragalus point is the highest spot on the axis of its trochlear surface. In Plate VI. it is marked by a cross. According to Meyer, the astragalus point falls, in a normal foot, within the triangle, but in a flat-foot to the inner side of the big toe line, i.e., the line connecting the heel and the head of the first metatarsal bone. The centre of gravity of the loaded astragalus then falls internal to the sole of the foot. From Plate VI., a drawing of the left flat-foot in my possession, it is seen that in that specimen, not simply the astragalus point, but the whole of the trochlear surface, lies internal to the big toe line. In a model foot there can be no doubt but that the centre of gravity of the loaded astragalus ought to fall within this triangle; but in a number of feet I have found it to fall either upon, or even a few millimetres to the tibial side of the big toe line.

In order to compare, by the measurements mentioned above, flat feet with normal ones, von Meyer selected three apparently well-formed feet; two of these he found to have their astragalus points internal to the sole triangle, in one case 1 mm., in the other 6 mm. He therefore classifies them with the flat feet. As feet with undoubtedly well-marked arches may have their astragalus points a few millimetres to the inner side of the big toe line, these cases might more correctly be regarded as possessing a mechanical tendency to the deformity, rather than as examples of slight flat-foot.

The axis of the trochlear surface of the astragalus is directed in my specimen to the inner side of the head of the 1st metatarsal bone, in a normal foot it is generally towards the interval between the 2nd and 3rd toes. In the same specimen the height of the upper surface of the astragalus above the base was 55 mm., it ought naturally to be about 80 mm. to 90 mm.

After the position of the astragalus had been determined it was removed and its surfaces examined. The changes in the shape of the astragalus are practically confined to its head and neck. I have already stated that its articular facets belonging to the ankle-joint are practically normal, and the same is the

case with its surfaces entering into the formation of the calcaneo-astragaloid joint. The only part of the body which is altered is its lower and outer angle. This lies just in front of its large concave facet. It is called, by von Meyer, the *processus fibularis* of the astragalus. When the astragalus is overpronated this process is pushed down into the depression on the upper surface of the greater or anterior process of the *os calcis*. According to Hueter, the depression becomes deepened and the process rounded. In this specimen the process was only slightly altered, but I noticed a facet on its anterior surface covered by articular cartilage. This facet came in contact with the outer part of the interosseous calcaneo-astragaloid ligament which separated it from the *os calcis*. On examining a number of recent bones I found that this cartilaginous facet is generally present, and that it articulates in the prone position with the interosseous ligament. This facet is about 5 mm. in height and about 15 mm. to 20 mm. in breadth. Its cartilage is continuous with that on the large concave facet, but the two surfaces are separated by a prominent border. So far as I know this facet has not been previously described, although it has a functional significance. When the astragalus is pressed upon from above, the descent of the body of the astragalus upon the *os calcis* is checked by the contact of this surface with the interosseous ligament.

Although the changes in the body of the astragalus are slight, those of the head are very decided. The outer and upper part of the head of the astragalus, in consequence of its displacement, is pushed against the scaphoid, and an abnormal facet formed. It is concave, somewhat round, and about 2 cm. in diameter. As a result of the pressure of the displaced bones the outer part of its neck is much shortened, and the upper part of the cartilaginous facet for the scaphoid is worn away. The cartilage covering the surfaces that articulate with the scaphoid and sustentaculum tali was normal, but that connected with the inferior calcaneo-scaphoid ligament was thickened, softened, and in a few places it was completely destroyed, and the subjacent bone was in a condition of porosis. This surface was undoubtedly larger than normal, and the inflamed condition may be attributed to the irritation resulting from pressure against the ground in standing or walking.

A. Ogston states that, in some cases, a prominent angle is formed on the head of the bone between this ligament and the scaphoid, which interferes with the restoration of the arch.

In Plate VI. fig. 2, a drawing is given of the dorsal aspect of the foot after removal of the astragalus. If this be compared with the appearances in a healthy foot, the changes in the os calcis, scaphoid, and inferior calcaneo-scaphoid ligament are very evident.

Os calcis.—This bone is altered in position in several respects. Its long axis is directed more towards the big toe than is usually the case, and its anterior end is lowered, so that the anterior tubercle rests upon the base. Still more marked is its rotation inwards. The valgus position of the os calcis can readily be seen either from above or from behind. In the view of the posterior surface the os calcis was seen to rest upon the internal tubercle, the external being raised above it so that a line connecting the two tubercles formed with the base an angle of 35° open to the outside. Professor von Meyer seems to consider that in a normal foot the external tubercle is rather lower than the internal one. He gives measurements, taken as above, of one normal foot and four flat feet. In the normal foot he found the tubercle line to form with the base an angle of 1° open to the inside. In the flat feet the average angle was $29^{\circ}5$ open to the outside. In one of the flat feet the angle was 43° , so that in the latter case the difference between it and the normal would be 44° . I think these measurements exaggerate the degree of valgus of the os calcis, as in the feet I have examined, with the leg vertical, I always found that the internal was the lower of the two tubercles, and consequently there was an angle opened to the outside. There can be no doubt but that this angle is increased in flat-foot, but the deviation from the normal is not so extensive as given by Von Meyer. In looking at the bone from above, the larger articular facet looks more inwards than normal, and the sustentaculum tali is much nearer the base.

The changes in the position of the os calcis are more marked than those of its shape. I have already referred to the facets formed upon its outer surface, which articulate with the fibula. In my specimen the cartilage covering the facet on the anterior process of the os calcis had been completely destroyed, and the

exposed bone was soft and spongy. A rough ridge was developed on the anterior part of the upper surface, which projected nearly three-quarters of an inch above the level of the cuboid, and its anterior edge somewhat overlapped it.

According to Hueter, the sustentaculum tali is much lower in relation to the body of the bone at birth than in the adult. By the prone position of the foot, this process is relieved of pressure, and grows upwards into a higher position in relation to the rest of the bone. Flat-foot, being an excessive pronation of the sustentaculum tali, grows still higher than its normal adult position. At page 1088, of his *Grundriss der Chirurgie*, he gives a view of the inner surface of the os calcis of a new-born child and of an adult. I cannot agree with these statements of Hueter, having satisfied myself, from an examination of the os calcis in newly-born children, that the sustentaculum tali has then practically the same relative height to the body of the bone that it has in the adult. Of course if the bone be rotated inwards the sustentaculum tali will be depressed. This is what has been done in Hueter's drawing of the infant's os calcis. If it be compared with his drawing of the adult bone, it will be at once apparent that in the former the bone has been rotated inwards, as much more of the upper surface of the body of the bone is shown in it than in the adult specimen. Again, in neither of my specimens of flat-foot is the sustentaculum tali higher in relation to the rest of the bone than in an ordinary adult.

Scaphoid.—This bone had no distinct alteration in its shape except the presence of a facet for articulation with one already described on the head of the astragalus. The pressure of the astragalus had worn away the upper part of the cartilaginous facet for articulation with the head of the astragalus, and also part of the upper surface of the scaphoid.

Inferior Calcaneo-Scaphoid Ligament.—This is generally described as being increased in length, and indeed this is often regarded as one of the principal causes of the descent of the head of the astragalus. As I have already stated, Von Meyer asserts that it is not increased in length. He measured it in six normal feet and five flat feet. In the former it varied from 27 mm. to 37 mm., in the latter from 27 mm. to 40 mm., from which it appears that the difference was very slight.

Professor von Meyer's plan for measuring it is not, I believe, a very satisfactory one. He measured it on the plantar surface from the most anterior part of the sustentaculum tali to the highest point on the tuberosity of the scaphoid. The question can easily be settled by an examination of the ligament from above, although, from the sustentaculum tali being placed obliquely in relation to the scaphoid, it is difficult to find a satisfactory point to measure from. If this surface of the ligament be examined it will be seen to be strengthened by fibres running from the sustentaculum tali, at the juncture of the facet on its upper surface with that on the upper surface of the greater process, forwards and outwards to the outer part of the under surface of the scaphoid. Measuring, in this situation, from the sustentaculum tali to the scaphoid, I found that in two normal feet the distance was 19 mm., in another, 22 mm., while in the left flat foot it was 35 mm. Independent of measurements the general increase in size of the ligament is quite apparent; at the same time this increase affects the inner much more than the lower part of the ligament.

The changes in the anterior part of the foot were much less marked than those already described in connection with the posterior part. The scaphoid, internal cuneiform, and first metatarsal bones rested upon the ground. On opening the calcaneo-cuboid joint the under surface of the rough ridge on the os calcis, overlapping the cuboid, was found to be smooth, and to articulate with the cuboid. The transverse arch, formed by the three cuneiforms and the cuboid, was diminished.

Although the bones forming the inner arch of the foot rested upon the ground, the outer border of the foot was not raised, so that the term flat-foot or pes planus is a very appropriate one for this condition.

The first step in this deformity is an over-pronation of the astragalus. This movement is checked by a number of powerful ligaments, especially the interosseous calcaneo-astragaloid, inferior calcaneo-scaphoid, internal calcaneo-astragaloid, and internal lateral ligament of ankle. In a well-developed foot, in which the muscles had been dissected, but the ligaments still entire, I divided the inferior calcaneo-scaphoid ligament and made firm pressure, through the tibia, upon the astragalus. This failed

to produce any abnormal displacement of the astragalus. I then divided in the same foot the interosseous calcaneo-astragaloid ligament with a similar result. Cases have been recorded of flat-foot resulting from a wound on the inner part of the foot, dividing the inferior calcaneo-scaphoid ligament and tibialis posticus muscle. In such cases the ligaments remaining entire will be subject to extra strain, and flat-foot will gradually result from their relaxation.

EXPLANATION OF PLATE VI.

Fig. 1. View of the dorsum of the foot in a specimen of flat-foot to show displacement of astragalus. Lines connecting *a*, *b*, *c*, form triangle representing sole of foot. The cross on astragalus represents "astragalus point," *d* and *e* the facets on outer surface of os calcis.

Fig. 2. View of the dorsum of the same foot after removal of astragalus. *a*, sustentaculum tali; *b*, inferior calcaneo-scaphoid ligament, *c*, posterior surface of scaphoid; *d* and *e*, same as before; *f*, abnormal facet on scaphoid.

A NEW METHOD OF CUTTING SECTIONS FOR
MICROSCOPICAL EXAMINATION. By JAMES W.
BARRETT, M.B., M.R.C.S., *Demonstrator of Physiology at
King's College, London.*

THE method of cutting sections here described, has but recently been introduced into this country; it is known as the "Celloidin method," and was first adopted for preparing extensive sections of eyes, with the parts *in situ*. Comprehending its great advantages over the ordinary methods, I have extended its use to all solid organs and tissues (pathological and histological), which require it, and believe that, where either *moderately thin and very extensive*, or *very thin and moderately extensive* sections are required, it will supersede the methods usually employed. With either object in view the preliminary process is as follows:—"The fresh tissue, suitably divided in the usual way, is hardened in Müller's fluid for from three to four weeks, the fluid being changed almost every day at first, then every two or three days, and subsequently at an interval of a week. It is then hardened in methylated alcohol for about a fortnight, and is finally transferred for a day or two to absolute alcohol. It is next placed in a *thin* solution of celloidin in equal parts of absolute alcohol and ether, and left there for a few days." (Celloidin in the solid form, or in solution, may be obtained from Zimmerman, Mincing Lane, London, E.C.)

If the very thin sections be required, the pieces put into the solution should be small. If the extensive sections are required the pieces should be of the required size and very thin, so as to allow the celloidin solution to penetrate easily.

They are next removed and placed in paper boats, which are then filled with this solution and are exposed to the air. When the ether and alcohol have been allowed to evaporate for some time, a crust forms on the surface. The boats are then immersed in a mixture of methylated alcohol and water, the specific gravity of which should be, it is said .820. As a matter of fact, any approximate mixture will answer equally well. They are left floating in this mixture for about three days, when the celloidin becomes very solid though elastic, and firmly imbeds the specimens.

They are now ready for cutting, but before describing the method of cutting, it is necessary to point out, that although other means may be found equally efficacious in effecting this preliminary process, yet that a careful attention to the most minute details will prevent much disappointment, until the worker is thoroughly conversant with the method.

It will be seen that the whole object is to infiltrate the tissue with a very coherent transparent material, which will not interfere in any way with the manipulation of the specimen after it is cut, and will permit either of very thin or of very extensive sections being obtained. I think every one will agree that by the ordinary gum and freezing method both these results are in most cases difficult to attain with any degree of certainty.

In order to cut *very thin and moderately extensive sections* the paper is torn from the boats, the superfluous celloidin is removed from the specimen, which is then placed in water for twenty-four hours, the water being changed frequently. It is next put into the ordinary freezing gum for a little while, and is then frozen and cut into sections by any of the ordinary freezing microtomes.

One point deserves attention. The specimen, when frozen, becomes very hard, and if the axis of movement of the knife is at right angles to its long dimension, the specimen will in all probability be uneven and wrinkled. The knife should be directed as obliquely as possible, otherwise the result often disappoints. The specimens are removed from the knife with a brush moistened in warm water and are then placed in water. If they are crumpled, they had better be transferred from the water to spirit and from spirit back to water; this little manœuvre, which lasts less than a minute, rarely fails to unfold them. They are next stained with any of the stains that are preferred, and are subsequently dehydrated *very carefully and thoroughly*. Ultimately they are placed in oil of Bergamot in order to clear them. Oil of cloves dissolves the celloidin, and the sections then usually fall to pieces.

After clearing, which is rapidly effected if the dehydration has been perfect, they are placed on a slide and are mounted in balsam. Oil of Bergamot does very well for clearing, but I am not sure yet whether any of the other essential oils are superior to it.

The preparation of *very extensive and moderately thin sections* can be effected by special microtomes obtainable from H. Katsch, of 25 Bayerstrasse, Munich, by which sections from 3 to 16 cm. in diameter can be prepared. The machines are so arranged that a long knife works with an oblique action and cuts the sections under methylated spirit. In preparing the specimen for cutting, the paper is removed from the boat in which it is contained, and it is then attached to a plate sunk in a trough full of spirit. The plate is raised by a screw, and so the thickness of the section is regulated. This method is of especial value for cutting sections of eyes, the parts being maintained in perfect position.

It would be injudicious to make any absolute statements as to the value of these methods, since there may be faults which I have not discovered, but it is my opinion at present that the method must come into general use and supersede the ordinary methods of section cutting. The chief obstacle at present is its expense. Celloidin itself is, when in the solid form, a firm white material, which can be dissolved in absolute alcohol, or in ether, or more rapidly in a mixture of the two. It is insoluble in water, and in mixtures of spirit and water. In effecting the dehydration of the sections, methylated alcohol (which is not absolute) should therefore be used.

In conclusion, I would recommend very strongly that any one who works with this material should for a time follow the directions given, or they will, like myself, at first be greatly disappointed. I should add, too, that Dr Hebb of the Westminster Hospital was kind enough to give me some very valuable assistance in the matter, which greatly aided me when I began to work at this method.

**A NEW METHOD OF DEMONSTRATING SCHEINER'S
EXPERIMENT.** By JAMES W. BARRETT, M.B., M.R.C.S.,
Demonstrator of Physiology at King's College, London.

It has frequently been noticed that the cause of the comparatively rare cases of monocular diplopia is some more or less linear opacity in the refracting media of the eye, which divides the aperture into two parts. If then the refraction of the eye be at fault, and the ciliary muscle be incompetent to correct it, diplopia results. In the case which came under my observation, the patient, who had a corneal opacity, about 6 mm. \times 2 mm. was having his refraction tested by retinoscopy, the pupil being dilated and the ciliary muscle paralysed with homatropine. The opacity was oval in shape, and stretched obliquely across the cornea so as to partially divide the visible pupil into two parts. On placing a negative glass (-5 D) in front of his eye he was rendered artificially hypermetropic, and his ciliary muscle being paralysed he was unable to correct it. The rays of light, being thus admitted into a hypermetropic eye by two apertures, did not meet on the retina, consequently two images were formed, and diplopia resulted. This may be regarded either as a demonstration of the artificial production of monocular diplopia or of Scheiner's experiment.

AN ABNORMAL DISPOSITION OF THE COLON. By
R. BRUCE YOUNG, M.A. M.B., *Demonstrator of Anatomy,*
Glasgow University.

THE following observations were made in the dissecting-room of Glasgow University, the subject was a middle aged female :—

Description.—On opening the abdomen the coils of the small intestine were found lying on the right side, while the cæcum was situated in the left iliac fossa. From the cæcum the great intestine ascended on the left side of the middle line, bound down to the posterior wall of the abdomen, and lying at first alongside of and immediately internal to the lower part of the descending colon. As it passed upwards, however, the ascending crossed in front, and then lay to the left of the descending portion of the colon, which, with the sigmoid flexure and the rectum, occupied the normal position. These two portions of the colon—ascending and descending—as they lay alongside of one another, were closely bound together by membranous adhesion. The continuity of the two parts of the colon in the left hypochondrium could not be made out in the undissected state, owing to the presence of a thin membrane which completely shut off from view the upper part of the abdomen—this membrane being reflected from the posterior wall of the abdomen and from the surface of the ascending and descending parts of the colon to be attached to the anterior abdominal wall in a line corresponding with the lower margin of the costal cartilages on the left, and of the liver as far as the gall bladder on the right side. Where the membrane was reflected from the surface of the ascending part of the colon, it projected downwards in two pointed folds, one on each side of the intestine. This membrane, passing across the upper part of the abdomen, concealed not only the continuity of the course of the colon, but also the stomach and the beginning of the duodenum, the spleen, and the left portion of the liver. By means of a subsequent dissection, made by dividing the membrane from below and the left part of the diaphragm from above, the abrupt curve, in the region of the spleen, by which the ascending passed into the descending

portion of colon was seen, and thus the whole extent of the great intestine, consisting of ascending and descending parts, sigmoid flexure and rectum, could be traced as it lay entirely on the left side of the abdomen. The transverse diameter of the ascending part measured $2\frac{3}{4}$ inches, being almost twice as great as that of the descending part. The whole length of the great intestine was 3 feet $7\frac{1}{2}$ inches.

The œsophageal end of the stomach lay directly in front of the aorta, and from it the stomach curved downwards to the left and then inwards again to its pyloric end, which did not cross the middle line, but lay over the aorta just above the point from which the inferior mesenteric artery was given off. Thus the œsophageal and pyloric ends of the stomach were situated in one vertical line, the stomach being entirely confined to the left side. A vertical distance of three inches separated the œsophageal and pyloric ends of the stomach.

The anterior surface of the stomach was attached by numerous bands of adhesion to the under surface of the left half of the diaphragm, while posteriorly the lesser sac of the peritoneum and the foramen of Winslow were obliterated by adhesions, which bound the posterior surface of the stomach to the abdominal wall. The layers of peritoneum, passing from the anterior and posterior aspects of the stomach, were continuous with the membrane which shut off the upper part of the abdominal cavity. So that this membrane was probably the great omentum adherent to the anterior wall of the abdomen.

The liver was firmly bound by adhesions to the under surface of the diaphragm. The duodenum, in its course from the pyloric end of the stomach, passed to the right, closely bound to the under surface of the liver, making a curve forwards round the fundus of the gall bladder, to which it was also adherent. Extending downwards from the inner side and apex of this curve of the duodenum, in the vertical antero-posterior plane, was a membranous layer, about two inches broad and one inch long, which lay two inches to the right of the middle line of the abdomen, and was attached below to the upper surface of the mesentery. There was thus a continuity of adhesion at this point between liver, duodenum, and upper surface of mesentery—a fact which, as will be seen, bears most importantly on the explanation of the present abnormality.

After curving round the gall bladder the duodenum ran upwards and backwards, and then turned inwards to its junction with the jejunum, close by the right side of the vertebral column about two inches below the origin of the superior mesenteric artery. A band of fibres tightly stretched was found extending from the point of union of the duodenum and jejunum obliquely upwards across the aorta to the connective tissue around the coeliac axis on the left side—the musculus suspensorius duodeni.¹

From this point the small intestine was traced downwards on the right side close to the middle line, as far as the upper part of the right iliac fossa, from which it ascended in the right lumbar region to the anterior surface of the lower end of the right kidney. In the whole of this part of its course the small intestine and its mesenteric attachment were bound down to the posterior abdominal wall by adhesions, but the remainder of the small intestine, as far as its junction with the colon in the left iliac fossa, lay, free from adhesions, in the fold of the mesentery, whose line of attachment to the posterior wall of the abdomen ran from the region of the kidney on the right side obliquely downwards across the middle line to the left iliac fossa. The small intestine measured 20 feet 5 inches in length.

The pancreas in its undisturbed position crossed over the origin of the superior mesenteric artery, and lay with its head in the concavity of the curve made by the duodenum round the gall

¹ Treitz, *Vierteljahrsschrift für die practische Heilkunde*, Prag. 1853, Bd. i., S. 113, quoted by Luschka, *Anatomie des Menschen*, vol. ii., p. 207. Quain, 7th edit., p. 840. Cruveilhier, *Anatomie Descriptive*, vol. ii. p. 132. This band, as Professor Cleland is in the habit of pointing out in his lectures, seems to have more importance than is usually attributed to it, for it is owing to its agency that the lower end of the duodenum always retains a fixed position, no matter how much the rest of the duodenal curve may be displaced. The duodenum may curve downwards even as far as the right iliac fossa, and yet its junction with the jejunum is always on the left side of the superior mesenteric artery, beneath the transverse mesocolon, and in the last inch or so of its course it is always vertical, owing to the suspension of this part of the small intestine by the musculus suspensorius duodeni. The usual description of the duodenum, as consisting of superior, descending, and transverse portions is incorrect, in that it makes no mention of this terminal vertical portion, and thus fails to note the manner in which the musculus suspensorius duodeni acts on this part of the intestine.

bladder. Owing, however, to the depressed position of the pylorus the pancreas was on a higher level than the pylorus.

On dissecting out the vessels the superior mesenteric artery was found coming off below the cœliac axis, but, passing in the upper part of its course to the right instead of to the left of the aorta, it ran downwards to supply the whole of the small intestine except 3 feet 10 inches at the lower end. Instead of giving off a number of separate branches to the small intestine, this artery divided into three large branches. Two of these, to the upper part of the small intestine, were given off from the right side of the parent trunk, while the third, the terminal branch, was distributed to the greater part of the bowel supplied by the superior mesenteric artery.

The inferior mesenteric artery, just at its origin from the aorta, turned sharply across to the right, and then passed in a gentle curve downwards to the left, to supply the lower 3 feet 10 inches of the small intestine, which did not receive branches from the superior mesenteric. From the left side of the inferior mesenteric artery, 2 inches from its origin, a small branch was given off, which extended across the middle line, and bifurcated to supply the ascending and descending portions of the colon. A common trunk, springing from the aorta immediately beneath the origin of the inferior mesenteric, gave off the sigmoid and superior hæmorrhoidal branches, and from the left side of the aorta at the same level an accessory renal artery passed to the left kidney.

The inferior mesenteric vein crossed the middle line obliquely, just above the origin of the inferior mesenteric artery, to join the superior mesenteric vein, which accompanied its artery, at a point an inch before the communication of the superior mesenteric and splenic veins.

Causation of the Preceding Abnormalities.—The most prominent features of this case were the position of the large intestine, consisting only of an ascending and descending portion, in the left side of the abdominal cavity; its length, 3 feet 7 inches; and the displacement of the junction of the duodenum and the jejunum to the right side of the aorta. The displacement to the left, and arrest in growth of the large intestine, are two facts which, though intimately related, must be distinguished from one another. In

publications on this subject several cases are recorded, in which the large intestine has been found on the left side of the abdomen. Some of these are referred to by Mr Lockwood in his paper "On Abnormalities of the Cæcum and Colon with reference to Development" (*Brit. Med. Journal*, 1882, vol. ii. p. 574), in which there is a full account of the literature of this subject. Dr John Reid describes two such cases (*Edin. Med. and Surg. Jour.*, vol. xlv., 1836, p. 70), but in both of these cases the cæcum lay in the left lumbar region, and the course of the large intestine seems to have been more complicated than in the present, while in a case reported by Dr Hilton Fagge (*Guy's Hospital Reports*, p. 345, Case 57), where the large intestine was on the left side, the cæcum was situated in the pelvis. Sir James Y. Simpson noted a case (*Edin. Med. and Surg. Jour.* 1839, vol. lii. p. 26), in which the whole of the large intestine lay to the left side, which case seems more nearly than the others to have resembled the present, though differing slightly, in that the ascending colon was nearer the middle line, and that the cæcum was retained by adhesions, which bound it to the lining membrane of the pelvis. In the cases reported by Dr Reid and Dr Fagge no explanation of the peculiar position of the intestine is offered, but Sir James Simpson points to the probability of the bands of adhesion having been the cause of the displacement in his case, though he admits that there is no positive proof that these adhesions "were formed at such an age as would have enabled them mechanically to effect the displacement of the caput cæcum." He, however, gives his opinion in favour of the view that peritonitis in the foetus is a common cause of abnormalities in the development of the intestines, and later writers, *e.g.*, Professor Turner (*Edin. Med. Jour.*, 1863, p. 113) and Mr Lockwood (*loc. cit.*) agree with him on this point. The difficulty in explaining cases of this sort seems to have been to prove that adhesions, when present, were due to peritonitis in the foetus, and not the result of a later inflammatory process, while in cases in which no evidence at all of inflammation has been seen the cause of the displacement has been further, if not absolutely, obscured. Yet it must not be supposed that the absence of all appearance of peritonitic adhesions and false membranes in the adult is a proof that there has been no previous inflammatory process, for, as Professor

Turner points out (*loc. cit.*), the observations of other pathologists have since confirmed the view put forward by Sir James Simpson, when he asks (*loc. cit.*) whether the absence of the adhesions, which led to the visceral displacement in the early fœtus, may not in some cases depend upon their absorption during the intervening period.

In the present case, however, the results of inflammation are abundantly evident in the adhesions which exist between the stomach, liver, intestines, and the abdominal walls, as well as between the different parts of the intestines themselves—so that the only question here is, whether these adhesions existed during foetal life in a position which would so affect development as to produce the individual abnormalities described.

Before proceeding to explain these abnormalities, it may be of advantage to note what the normal course of development of the intestines is. This has been described by Professor Flower (*Med. Times and Gazette*, 1872, vol. i. p. 291), and also by Professor Cleland in several of his papers (*Journ. Anat., and Phys.*, May 1868, May 1870, April 1883). These writers show that at an early period the alimentary tube is a mesial structure with a long loop projecting out at the umbilicus. The two ends of this primary loop are united by a narrow neck of mesentery, in which lies the trunk of the superior mesenteric artery, which is the artery of the loop. The upper end of this loop is at the pylorus, and from it the duodenum is formed, while from the lower end, at a later stage, the right half of the transverse and the whole of the ascending colon are formed by a process of elongation. The growth of this primary loop, therefore, takes place in two stages, the first a growth which, starting near the pylorus, forms the duodenum and elongates the whole small intestine, the second a growth from the colic end of the loop. When these two elongations from the upper and lower ends of the primary loop take place, the direction of growth is in opposite directions in the two instances. In consequence of this, and owing to the narrowness of the neck of the primary loop of intestine, a crossing of the cæcum over the duodenum occurs, and thus after a time the cæcum comes to occupy its adult position. The non-occurrence of this twisting of the cæcum over the duodenum would therefore lead to marked

changes in the development and adult position of the intestines. Professor Cleland points out that, in addition to the primary, there are, in the developing alimentary canal, two secondary loops, one formed by the stomach above, and the other by the left half of the transverse and the descending colon below the primary loop. The arrangement of the vessels supplying the primitive alimentary tube corresponds with this separation of the intestine into three loops, the superior mesenteric artery going to the primary, the cœliac axis to the upper secondary, and the inferior mesenteric to the lower secondary loop, so that there are three loops or portions of the intestinal canal—a superior mesenteric, a cœliac, and an inferior mesenteric.

In the description of the present case, I pointed out that the mass of small intestine lay in the right side of the abdominal cavity, and that its upper part, where the duodenum joins the jejunum, was on the right side of the aorta, while the musculus suspensorius duodeni was tightly stretched across the aorta, indicating that some force had come into play, in order to effect this change in position of a part of the intestine which is normally situated to the left of the aorta. I also described the superior mesenteric artery as lying at its origin to the right instead of to the left of the aorta, and its branches to the small intestine, all coming off from the right instead of the left of the parent trunk. A similar arrangement of the superior mesenteric branches to the small intestine has been noted by Dr John Reid (*loc. cit.*), and also by Professor Chiene (*Journ. Anat. and Phys.*, 1868, p. 15).

The position of the point of junction of the duodenum with the jejunum, and of the upper part of the superior mesenteric artery on the right side of the aorta, prove that the cause which effected this change from the normal must have come into play in the young foetus, for, from a very early date in development, these two portions of the intestine and its artery respectively occupy a constant position on the left of the aorta, however indefinite the situation of the free coils of the intestine or the distribution of its artery may be. As further proof of the early date at which changes in development took place, the circumstance that the stomach was situated entirely to the left of the middle line, leaves little room for doubt that the adhesions

which were found in the adult fixing it in that position had been formed at a period of foetal life before the pylorus had passed to the right side to reach its normal adult situation, and thus the stomach was retained altogether on the left side of the abdomen

An examination of the abdominal viscera in a foetus about one and a half inches in length from the vertex to the coccyx affords strong proof in favour of this view, for there the stomach is found lying to the left of the mesial plane, with the folds of the great omentum hanging loosely from its inferior border, so that it is easy to understand how adhesion, as the result of foetal peritonitis, might take place between the folds of the great omentum and the anterior wall of the abdomen on the left side, and thus the developing stomach would in the adult continue in the position which it occupied in the foetus at the time when the inflammatory process occurred. The layers of the great omentum, adhering to the anterior wall of the abdomen, would form a membranous partition, shutting off the upper portion of the abdominal cavity, which partition persisting during growth explains the appearances here noted in the adult. During normal development, the crossing of the colon over the upper end of the primary loop, as the caecum passes to reach its ultimate position in the right iliac fossa, causes the small intestine to occupy partly the left side in the abdomen. Bearing, then, in mind the facts noted above, as regards the early date at which developmental changes must have taken place in the present case, and finding that the small intestine as well as its vessels are placed altogether to the right of the middle line, and that the large intestine, on the other hand, is wholly confined to the left, and only measures 3 feet $7\frac{1}{2}$ inches in length as compared with the normal 5 or 6 feet, it seems fair enough to assume that a change in the course of the large intestine must have taken place at a very early period in foetal life, before, in fact, the large had completed its twist over the small intestine. Thus the coils of the small intestine, occupying the right side of the abdominal cavity, would in the course of growth act on the point of junction of the duodenum and the jejunum, so as to drag it towards the right side of the aorta, and put on the stretch the fibres of the musculus suspensorius duodeni,

while the course of the vessels was correspondingly altered to the right side.

This non-occurrence of the twist of the colon over the duodenum is a point of the greatest importance, not only in that an explanation is thus afforded of the abnormalities in the present instance, but also because of the wide bearing that it seems to have in connection with abnormalities of the colon in general.

In the foetus already referred to, the stomach and intestines of which are above described, the cæcum is situated a little to the right of the middle line of the abdomen, having just passed to the right between the pylorus and the coils of the small intestine,—so that it is evident that a band of false membrane, passing in the vertical antero-posterior plane from the curve of the duodenum to the upper surface of the mesentery, would have prevented this passage of the cæcum to the right from taking place. Such a band of false membrane has been described in the present case. That it was developed as the result of a peritonitis occurring in the foetus, and formed an obstacle which prevented the twist taking place, so altering the course of the large intestine, is I think highly probable, not only because the date of the occurrence of the change in direction of the large intestine can thus be fixed to a time which is in harmony with the evidence on that point afforded by the other facts of the case, but because the explanation thus afforded of this primary alteration in the course of the large intestine enables us also to understand how the displacement occurred which resulted in the adult position of the portions of the large intestine. For if this band, passing from the duodenum to the mesentery, did check the progress towards the right, and passage over the duodenum of the cæcum and the developing colon, it follows that the further growth of the large intestine would cause the cæcum to glide downwards to the left of the coils of the small intestine, dragging with it the upper part of the inferior mesenteric loop of intestine, and the lower part of the small intestine, till the cæcum reached its adult position in the left iliac fossa, and the angle between the two portions of the inferior mesenteric loop being obliterated they came to lie side by side in the left half of the abdomen;

the greatly diminished length of the large intestine being thus in great measure due to the alteration in its normal course of development.

The two pointed folds which have been described as passing down, one on each side of the upper part of the ascending portion of the colon, from the undersurface of the adherent great omentum, are projections of peritoneum which have resulted from obliteration of the angle at the splenic flexure as the displacement of the colon took place.

Adhesions have been described between the two portions of the colon. These adhesions, if they occurred, as probably they did, at the same early date as the others, may, by binding the two portions of the colon together, have formed a secondary factor in determining, along with the inherent force of growth, the course of the cæcum towards the left iliac fossa. They also, no doubt, acted along with the displacement in preventing the growth of the colon.

I have already alluded to the position of the superior mesenteric artery and its branches, as proof of the early date at which changes must have taken place here. In the course and distribution of the inferior mesenteric we have, I think, still further confirmation of the view which has been taken of the date and manner of occurrence of the alteration in the course of development of the colon, and of its subsequent displacement. The peculiarity in the distribution of the inferior mesenteric artery was, that besides giving branches to the ascending and descending portions of the colon it supplied 3 feet 10 inches of the lower part of the small intestine. Now, supposing the change in course of the developing colon to have taken place at a stage of growth slightly earlier than that described in the fœtus which was examined, when only the inferior mesenteric loop of intestine, and none of the ascending or left half of the transverse colon, had as yet been developed, the right and middle colic branches of the superior mesenteric artery, which supply the ascending and right half of the transverse colon, could not yet have been developed, while the inferior mesenteric artery, with its branch which ascends to anastomose with the superior mesenteric, would be relatively perfect. So that, when the change in the course of development took place,

and the cæcum, with the end of the small intestine, passed down to the left iliac fossa, the lower portion of this small intestine would naturally come to receive most of its blood supply from the nearest source, viz., the inferior mesenteric, and, by enlargement of capillaries and arterioles, there would result the adult condition of a large branch of the inferior mesenteric for the lower part of the small intestine. The bend of the inferior mesenteric on itself at its origin is thus explained by the sudden downward displacement of the colon, which occurred after the primary arrest of the twist of the intestines, while the curve of the artery to the right may be accounted for by the mass of the small intestine on the right side acting on the developing vessel. The small size of the branch which supplied the two portions of the colon must be taken in connection with the great diminution in length of the large intestine.

Again, by the fact of the sigmoid and superior hæmorrhoidal branches being given off by a separate common trunk from the aorta, and by the presence on the left side of an accessory renal artery, further evidence is afforded of disturbance at an early period of the normal development of vessels.

This case then seems to have been one in which a peritonitis occurring in the early foetus led to the formation of adhesions and false membranes in various parts of the abdominal cavity. As a result of these formative changes following an inflammatory process, arrest of the twist of the large over the small intestine, and subsequent displacement of the colon, followed by transposition of the small intestine to the right side, as well as retention of the stomach in its foetal position, and various changes in the course and distribution of the intestinal vessels took place.

The chief point of interest in this case are (1) the persistence, in the adult, of the adhesions, which in foetal life gave rise to the abnormal disposition of the viscera, and (2) the non-occurrence of the twist in the developing intestine—a pathological fact, which, beyond the present instance, seems to be of importance in the causation of many abnormalities of the colon.

I wish to offer my heartiest thanks to Professor Cleland for his kind assistance in preparing this paper.

ON THE DELINEATION OF SKULLS BY COMPOSITE
PHOTOGRAPHY. By ARTHUR THOMSON, M.B., *Senior
Demonstrator of Anatomy, University of Edinburgh.*
(PLATE VII.)

HITHERTO, in the study of Craniology one of the greatest difficulties has been to obtain a skull of the race under examination, embodying all the peculiarities characteristic of the crania of that race, without at the same time giving undue prominence to personal or individual variations. Numerous methods have been employed to arrive at such a result, long and elaborate tables of measurements have been published, from which averages have been deduced, and indices adopted for the purposes of comparison. This arrangement is of much scientific value, but it must be confessed affords little information to those not versed in this department of science.

Whilst by no means depreciating the value of these measurements, I consider that a graphic method of comparison is at least the one which appeals most forcibly to the uninitiated, and which, in addition, presents certain other novel features worthy of note. That the value of a graphic method of comparison of crania has long been recognised, is fully proved by the existence of numerous instruments specially designed to enable the observer to make an outline plan or chart of the skull which he is examining; subsequently this chart may be made use of to measure certain angles or compare the distances between certain points,—of such a nature are the craniograph and stereograph of Broca, which are amongst the instruments most frequently employed for this purpose. Another and more direct manner of obtaining outlines of skulls is to make use of tracings taken from sections of the cranium, the vertical mesial section being the one usually adopted. This plan answers well to enable us to compare many important features, but is open to the objection that it necessitates division of the skull, liberty for doing which we unfortunately cannot always obtain.

The drawings obtained by the above or similar methods resemble an architect's plan, in that they are orthogonal pro-

jections, that is to say, they are not subservient to the laws of perspective, and hence measurements taken from them may be relied upon as correct.

Photography has not been extensively used in this department, as it has been open to the objection that the representations produced are perspective views of the skulls which have been "taken," and hence, portions of the skull nearer the camera will bear a relatively larger proportion to parts of the skull more distant than they do by actual measurement. This is doubtless true, theoretically, especially when a lens of wide angle and short focus is employed, but, practically, it is reduced to a minimum, and may be disregarded if we adopt the precaution of making use of a lens of long focus. By that means the distance between the object and the camera being greater, the convergence of the rays is less, and hence approaches more nearly to the parallelism of the rays in the orthogonal projection; in other words, if we wish to estimate the proportions of a large pile of buildings, we do not stand close to it, in which position we would fail to form any just conclusion of the relative height of the tower to the rest of the edifice, but, seeking some point at a considerable distance, we obtain a view of the structure bearing a striking resemblance to the architect's elevation of the same.

Again, the photograph has this great advantage over the projections already spoken of, in that, by the portrayal of the alternations of light and shade, it gives us a faithful representation of the surface contours of the skull.

With these remarks in defence and in favour of the means by which I was enabled to obtain the present results, the next difficulty was to procure a graphic type of a series of skulls, and here I must express my thanks to Mr Francis Galton for the suggestions on composite photography published in his work, *Inquiries into Human Faculty and its Development*. Composite photography has, since the publication of this work, been employed by numerous investigators, but, so far as I am aware, it has not hitherto been made use of in this connection.

Though the results which I publish at present are not so complete as I would have desired, yet I think that they are of sufficient interest to warrant attention being drawn to them.

For the purpose of comparison I have produced composite

photographs of Australian and European skulls, for the loan of which I am indebted to Professor Turner.

The Australian series consists of the photographs of eight male skulls combined, that of the Europeans being composed of the combination of four French male skulls. As will be seen from the plates, a profile and full-faced view of each series was obtained.

In order to procure these results attention had to be paid to the following points:—The skulls were photographed in a soft diffuse light, so that, as far as possible, strong contrast of light and shade was avoided; this was found necessary, as in the composite printing the thin portion of one negative might obscure or overprint the details exhibited by another in the same situation; next, in taking the full-face views, I required to reduce skulls of different sizes to a common scale. This was accomplished in the following manner:—A *vertical* line was drawn through the centre of the screen of the camera, and on this line two points were marked off, which, as each skull was focussed on the screen, were made to correspond to the fronto-nasal suture and superior alveolar border respectively. By this arrangement the distance between these points in all the skulls was reduced to a common measure, a fact which was taken advantage of in the further operations as a base line on which to key the plates. Whilst focussing, care was taken that the vertical line on the screen overlay the intermaxillary suture inferiorly and the suture between the nasal bones superiorly, as seen upon the ground glass. Care was also taken that equal halves of the skull appeared on either side of this vertical line, and in order to ensure an accurate correspondence of the photographs with each other, it was further necessary to place all the skulls in the same horizontal plane, the plane chosen being that which passes through the lower orbital margin anteriorly, and the upper part of the external auditory meatus posteriorly.

In taking the side views of the crania similar precautions were observed. Unfortunately for reasons connected with the apparatus at my disposal, I was unable to photograph the profile views on exactly the same scale as the full-face views. As the side views of the French and Australian series are reproduced to the same scale, they may be readily compared with each other. In this

instance a *horizontal* line was drawn across the screen of the camera, and this line was made to occupy the horizontal plane already spoken of. As the image was focussed, a point was then taken on this line which was made to correspond to the upper part of the external auditory meatus, the line anteriorly passed through the inferior orbital margin, anterior to which another point was taken, to which the free margin of the nasal process of the superior maxilla was made to correspond. In this way a base line was obtained, which was of equal length in all the negatives, and which was made use of in the subsequent stages of the process in a similar manner to the vertical line in the full-face series. I may here state that, in using the terms superior and inferior in regard to the skull, I have disregarded the inversion of the image upon the screen of the camera. I was thus enabled to obtain two negatives of each skull in the series, one a face, the other a side view.

My next object was to procure a graphic type, by combining the negatives of the different series. This was attended with considerable difficulty, and it was only after repeated trials that I adopted the following plan:—The negatives were taken, and lines at right angles to each other were drawn through certain corresponding fixed points on the different plates, the vertical and horizontal lines I have already mentioned being made use of as bases upon which to superimpose the different images. I was thus enabled to key the negatives on to a sensitive plate in the same manner in which a lithographer registers his proof on the stone. By exposing this sensitive plate to light under successive negatives, I obtained a *composite* positive, from which I again printed a glass negative by super-position, from this *composite* negative I was then able to print off any number of silver prints. The plates which accompany this paper are reproduced from the *composite* negative by means of a photo-mechanical process, which, if not securing as perfect a result as the silver print, at least preserves the faithfulness of the original.

A glance at the plates will show that, though the individual skulls of the different series varied much in size, yet when reduced to a common scale they display a remarkable similarity in their contours and modelling. But, in addition to displaying

what we may term the typical appearances of the crania of the group, individual variations are also represented, as shown in Plate VII. figs. 2 and 4. In fig. 2 we observe the outline of a skull, the highest point of which is placed higher and more posterior than that of its fellows. Again, in fig. 4 we notice an outline which, from the fronto-nasal suture to the inion, far exceeds that of any of the other crania in the same series,¹ and yet it is worthy to note how remarkably the contour of this line resembles those which lie immediately within it. As individual variations in this figure, we may draw attention to the varying projection of the superciliary arches.

It is hardly necessary to contrast the types of the two series, as the plates speak for themselves, but it may be as well to draw attention to one or two points.

In the full-face views of the Australian and European types, the marked difference in the general contours is at once evident, but in addition the figures also display notable differences in the shape and size of the orbits, as also in the appearance presented by the anterior nares. The difference in build of the malars and superior maxillæ is well shown, and the character of the frontal region well contrasted.

In studying the profile views, it is curious to observe how closely the outlines overlies one another, inferior to a line drawn from the external occipital protuberance to the fronto-nasal suture. The difference of contours in figs. 2 and 4 is evident, and it is interesting to see how straight the outline from mastoid process to external occipital protuberance is in fig. 4, also how this latter point very nearly approaches the maximum occipital point, whereas in fig. 2 the inion lies much anterior to it.

Fig. 4 as contrasted with fig. 2 also shows well the forward thrust of the superior maxillæ with a corresponding elongation of the zygomatic arches whereby the prognathism of the skull is produced.

There is doubtless much room for improvement in the production of these composite prints which experience only will teach

¹ These Australian skulls have been described by Professor Turner in his Report on the Crania of the Challenger Expedition, and profile and full-face views of this skull from the Riverina, N.S.W., are given in plate ii. figs. 1, 2, *Zool. Chall. Exp.*, part xxix., 1884.

us, still I think that already sufficient has been shown to prove the utility of such a method in comparing and contrasting type skulls of the different races.

EXPLANATION OF PLATE VII.

Fig. 1. Composite photograph of four French crania, full-face view.

Fig. 2. Profile of the same.

Fig. 3. Composite photograph of eight Australian crania, full-face view.

Fig. 4. Profile of the same.

[This Plate will appear in the January number of this *Journal*.]

REPAIR OF WOUNDS AND FRACTURES IN AGED PERSONS. By Professor HUMPHRY.

It will have been observed by others, as well as by myself, that ulcers heal quickly in old persons; and that the processes of granulation and cicatrisation proceed in them, on the whole, with even greater rapidity than they do at earlier periods of life. We see this more especially in the leg, because ulcers are much more frequent in this region than in other parts; but the observation is not confined to them. I have noticed this reparative activity in the aged under many circumstances and in various parts of the body; and, my own experience indicating that the same holds good with regard to wounds and fractures, and that the commonly received opinion to the contrary on this head is erroneous, I ventured, in a note recently printed in the *British Medical Journal*, to ask for information from others, that I might ascertain whether their experience accorded with my own.

My attention was first directed to the subject by the case of a man, aged 88, who consulted me many years ago respecting a warty growth, with some ulceration, on the lower lip, which annoyed him, and which he wished to have removed. I excised a large piece of the lip by the usual V-incision, and the wound healed as rapidly and firmly as any of the kind I ever saw. About the same time, I operated for femoral hernia on a feeble woman, aged 75, and the wound was soundly healed in three days. Several similar cases have come under my own notice, and some have been sent in answer to my inquiry; not so many as I could have wished, but enough to establish the fact of the quick union of wounds in old people.

The statement must be qualified in a manner which savours rather of the paradoxical; namely, that wounds in old people heal quickly, provided they do not slough. That is to say, the apparently opposite tendencies exist at this time of life—namely, the tendency to slough and the tendency to heal quickly. Such, for instance, is the observation of oculists, whose testimony on the subject I have asked. They find that the cornea sometimes sloughs after the operation for cataract in old people; but that, when it does not slough, the wound heals quite as quickly as, or more quickly than, at an earlier time of life. So in other operations. The old person may sink, or the wound may slough or ulcerate; but, if these eventualities are escaped, a quick healing may be expected.

Certainly this would not have been anticipated. We should not have thought that, when the nutritive forces are generally failing, when strength and weight are diminishing, when repair is each year less and less able to keep pace with wear, as evinced, among other things, by the fact that exhaustion is more quickly induced and less quickly recovered from; when the brain is shrinking, and memory

and other mental powers are lowering, and when the circulation is becoming weaker,—that, under these circumstances, the nutritive or reparative processes concerned in breach-closing, in the healing of wounds and ulcers, should manifest an increase of energy, at any rate, of rapidity, in carrying on their work. I do not know well how to explain it; but this exceptional phenomenon of nutrition is not peculiar to old age. It may be observed in some other lowered conditions. The wounds in patients exhausted by large losses of blood usually heal quickly, as they also do after operations for cancer, and in many other debilitated conditions. I do not mean persons of naturally strumous temperament, but persons who have been weakened by illness or in other ways. So do, commonly, the gaps caused by carbuncles, and bed sores; and very remarkable is the quick healing of the stump left by the separation of the parts in senile gangrene—that is to say, this evidence of vital energy is manifested in the part next above that which was unable to keep alive at all: and, after fracture of the spine, we sometimes see quick sloughing and quick healing in closely adjacent parts. An exception must be made of certain impaired conditions of the nervous system in which wounds and sores are sometimes very troublesome.

The remarks I have made with regard to the repair in wounds and ulcers in old persons hold good also with regard to fractures. This is sufficiently proved by the cases given in reply to my inquiry; and in one of these, it was remarked that the limb in which the fractured tibia and fibula united in three weeks was partially paralysed and nearly useless, the knee being contracted; and in another case, the broken tibia in a most enfeebled helpless woman of 68 was pretty firmly united in three weeks.

Professor Gross, in his *System of Surgery*, observes that age is no barrier to union, and mentions the case of a lady, aged 100, in whom union of a fractured humerus took place in the usual time; and that of a woman, aged 93, in whom a fracture of the upper third of the thigh was united in three weeks.

The contrary view, however, is prevalent. In Holmes's *System of Surgery* it is stated, that "in old age, the period is greatly protracted in proportion to the want of vigour of the individual." Chelius remarks that in advanced age the bone heals with difficulty. In the *International Encyclopædia of Surgery* a doubtful opinion is given; and the prevailing impression respecting the time required is probably to be attributed not so much to observation of the fact as to an *a priori* feeling that it is likely to be so; for we know how often that which is probable is assumed to be that which is real.

Moreover, the circumstance that fractures of the neck of the thigh-bone, which may be regarded as the old person's fracture, commonly does not unite at all by bone, the broken ends in many cases remaining quite separate, seems to give support to the view. It is well known, however, that this failure depends, not upon the age of the patient, or on any peculiarity in the structure of the bone, or upon any changes that take place in it during the later periods of life, though those changes are such as to cause rarefaction of its cancelli and greater

liability to fracture, but upon other causes. Such causes, more particularly, are the separation of the broken surfaces, which commonly occurs; the buried position of the inner fragment in the cavity of the acetabulum, which prevents any overlapping of the fragments and any throwing out of uniting matter around it; as well as the comparative absence, and, when the fibrous covering of the neck is torn through all round, the complete absence of tissue in which that material can be produced; and also the bathing of the fractured surfaces by the synovial fluid. That these conditions, which are found to be more or less prejudicial to bony union of fractures into other joints, and not senility, are the real causes of failure in the case of the neck of the thigh-bone, is proved by the fact that union by bone will take place at this part of the skeleton as well as elsewhere, if the fractured surfaces be fixed in apposition, either by any kind of impaction or by well-adjusted appliances; and that this will occur in the aged has been often proved, and as is well shown by a specimen of firm bony union in a gentleman, aged 81, who broke the neck of his thigh-bone a year before death. The treatment was very carefully conducted by Mr Wherry, who was near by at the time of the accident, and who, recognising the nature of the case, took every precaution to prevent further displacement of the fractured surfaces; in seven weeks union had taken place so firmly that the patient could raise the limb from the bed by the action of the muscles of the hip. The breakage was close to the head of the bone, as is shown by a line of fibrous tissue joining the fractured surfaces in the hinder part; whereas, in front, the union by bone is so complete that it is difficult at first sight to determine the line of fracture.

Notes of several cases have been sent me, in which union of broken neck of the thigh-bone in old persons was believed to have taken place, and in a short space of time; but, as the condition of the parts has not been verified by examination, and as in such cases it is almost impossible, without ocular inspection of the part, to determine whether bony union has actually taken place, I have thought it better to omit them from the series.

In the case of fractures, as in the case of wounds, a certain amount of nutritive vigour is necessary to bear, and turn to good effect, the vascular and other changes in the tissues associated with the work of repair; and, unless that exist, destruction by liquefaction or absorption of tissues may take place, instead of the condition requisite for healing. In the bones, indeed, a certain amount of absorption is the regular attendant upon repair. By it the surfaces in the proximity of a fracture are roughened, and rendered porous to admit the new uniting material—the soft callus-medium—to grow into and form one with them, just as the surfaces of a brick are rough, that the mortar may run into and set in, and adhere to them, and form a bond. Sometimes we find that, in old and very feeble people, the one requisite for reunion after fracture—the work of absorption or destruction of the broken ends—takes place in excess; whereas the other requisite—the work of forming the new uniting material—is deficient. Accordingly, the ends of the bones become porous and worm-eaten, and

little or no callus is produced. That has been the case in this oblique fracture of the humerus, which occurred in a feeble man of 86, while he was pulling himself upstairs by the handrail. He was afterwards extremely restless, so that no retentive means could be effectually applied; one of the broken ends made its way through the skin, and he died in three weeks. The bone is light, and is worm-eaten near the fracture, and there is only a little crumbling osseous deposit upon it. The same condition is seen in each of these two thigh-bones, one of which was taken from an aged subject in the dissecting-room, and the other bears all the mark of senility. I do not know the history in either case, but in both there are absence of new material and evidence of too free removal of the old.

In the contrasting features, therefore, of liability to utter failure of repair and demolition of the injured part on the one hand, and in that of quick repair on the other, the bones resemble the soft parts; and I trust that the question for the solution of which I have asked assistance has now been sufficiently answered. We have thus established the fact that the repair of wounds and of fractures takes place in the old persons as quickly as in the middle-aged; and we ought to hear no more of the disqualification for reunion which has been attributed to old age. That this is no unimportant matter from a practical point of view, is sufficiently shown by a case mentioned by Mr Hodson, of Bishop Stortford, in which a fracture of the thigh-bone in an old woman was allowed to go untreated, because the medical men thought that at that time of life union of a broken bone was not to be expected.

In conclusion, I have to thank the gentlemen who have been good enough to forward the cases from which these notes¹ have been taken; and I may remark that it is only by the collection of cases in this way these and many other questions can be answered. The investigation by this method, for which the British Medical Association affords such unprecedented opportunities, has the double advantage of bringing a heavy battery of information to bear upon any one point where information is required, and further, of greatly benefiting those who communicate the information. There is no reading at all to compare with that of reading ourselves, our own experiences, and our own thoughts upon them. These were the feelings which influenced me when I ventured at the Cambridge meeting, four years ago, to suggest that some measure of the energies of the Association should be turned in this direction. I have never taken any part in the political movements which occupy the attention of some of the more active members, being of opinion that greater service might be rendered to the Association, to its individual members, and to the science and practice of medicine, by organising a plan for the collection and utilisation of the vast streams of experience which are daily allowed to flow away into the great abyss of waste.

¹ See *British Medical Journal*, July 12, 1884, where these notes of cases, communicated by various medical men, will be found appended to the paper from which these remarks have, in the main, been taken.

A CASE OF ABNORMAL DEVELOPMENT OF THE CORONARY ARTERIES OF THE HEART. By F. CHARLEWOOD TURNER, M.D., *Physician to, and Demonstrator of Morbid Anatomy at, the London Hospital.*

THIS abnormality consisted in the presence of a large branch of the right coronary artery, which passed backwards between the root of the aorta and the right and left auricles, and took the place of the posterior branch of the left coronary artery which had not been developed.

The right coronary artery arose in the normal position, from the anterior sinus of Valsalva. The trunk of the vessel, which was of large size, but not much more than $\frac{1}{4}$ inch long, ran forwards and terminated beneath the wall of the right auricle, immediately above the margin of the right auriculo-ventricular orifice. It there divided into two primary branches of equal size, which ran in opposite directions along the margin of that aperture. That passing forward to the left of the auriculo-ventricular orifice had the normal distribution of the right coronary artery. The other branch ran backwards and to the right round the root of the aorta, passing between it and the inter-auricular septum, to the margin of the left auriculo-ventricular orifice. Skirting the left extremity of the mitral slit in the auriculo-ventricular groove, it took the place of the posterior branch of the left coronary artery, whose area of distribution it supplied. From the trunk of the right coronary artery, quite at its commencement, a small branch was given off, which ran forward and to the left over the infundibular portion of the ventricle.

The specimen was obtained from the body of a man apparently between fifty and sixty years old, of whom nothing was known, who died in the street, and whose body was brought by the police to the London Hospital. There was much atheroma with dilatation of the aorta, and the orifice of the left coronary artery was contracted. There was also fatty atrophy of the myocardium.

This abnormality in the development of the coronary arteries of the heart resulted from an enlargement of the small circumflex branch of the right coronary artery. In a case of abnormal distribution of the coronary arteries observed by Bochdalek, and described in *Virchow's Archiv*, vol. xli., in which the left coronary artery was absent, its place was in part supplied by a branch of the right coronary similar to the above.

ABNORMAL URETERS. By W. STEPHENSON RICHMOND,
St Bartholomew's Hospital.

IN the dissection of a male subject, four ureters were discovered emerging from the hilum of each kidney. After proceeding about four inches towards the bladder they became united, forming a pelvis, from which sprang the ureter proper.

On making a section of one of the kidneys, the hilum was found to be occupied by a quantity of fat and connective tissue, imbedded in which the ureters could be traced to the infundibula, communicating with the calices and pyramids. Thus there was no pelvis within the hilum, but the calices united to form infundibula, of which these ureters seemed to be the continuation, and they became united in a pelvis some distance removed from the kidney.

The interest of the case is not entirely anatomical.

The man had evidently suffered from some bladder mischief, for the walls of this vessel were very much thickened and the kidneys themselves were enlarged. The question which raises itself is whether, presuming some difficulty existed in emptying the bladder, such a condition of things could be brought about by mere mechanical means, viz., by the pressure of the secretion from the kidney forcing down and elongating the infundibula to such an extent as that which I have described. I mention this as a possible cause, but I think it was really a matter of development. For in the same body there were other signs of abnormal urino-genital development. Attached to the hydatids of Morgagni were fibrous nodules which I have before described in this *Journal* (vol. xvii.), and which I shortly tried to prove were the remains of that portion of the Wolffian body which generally becomes obliterated. This being the case it is almost certain that they are both abnormalities of development. But had the former existed without the latter, one would have been more easily satisfied with a pathological explanation. Both the above specimens are preserved in the Museum of St Bartholomew's Hospital.



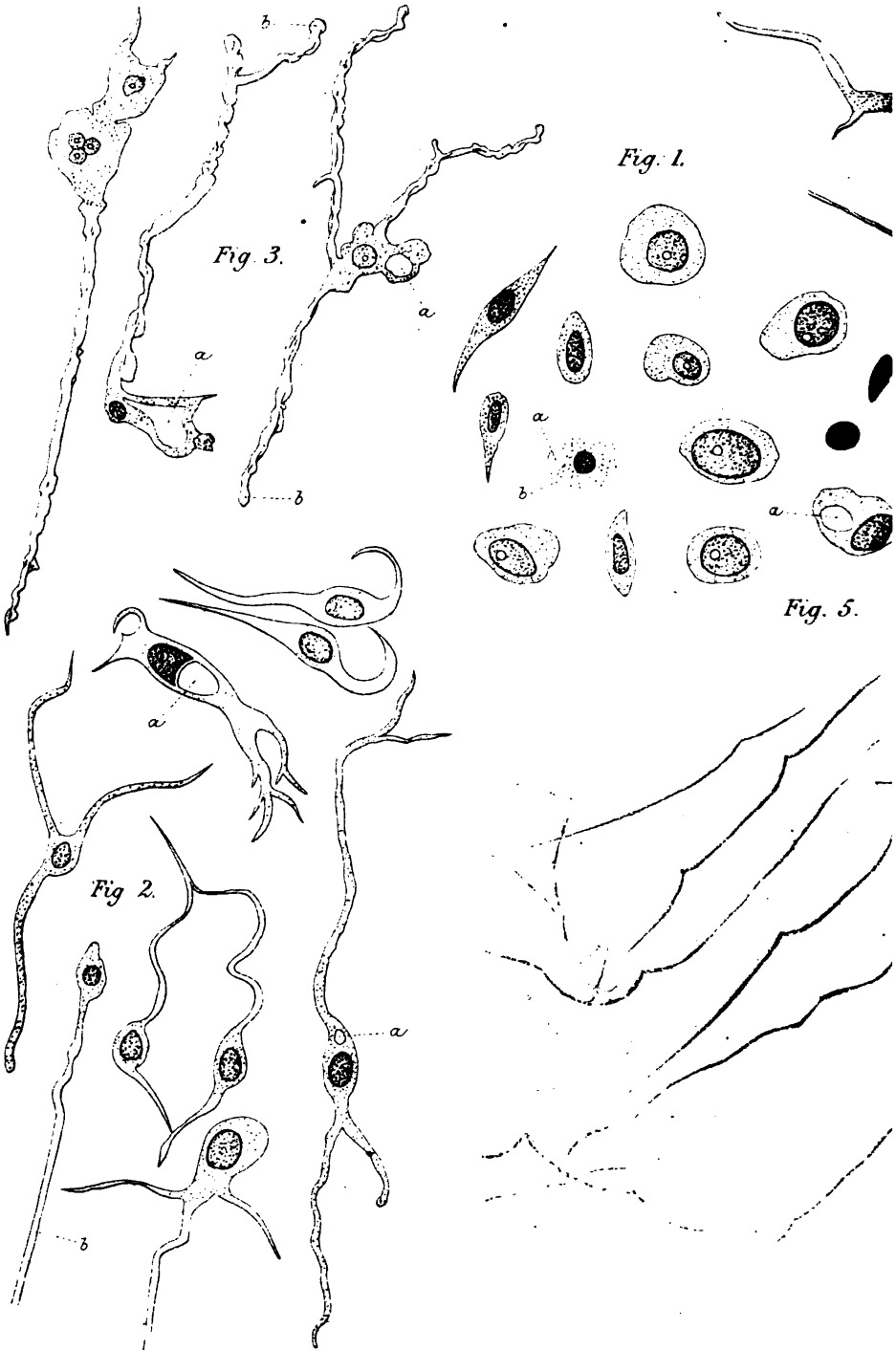
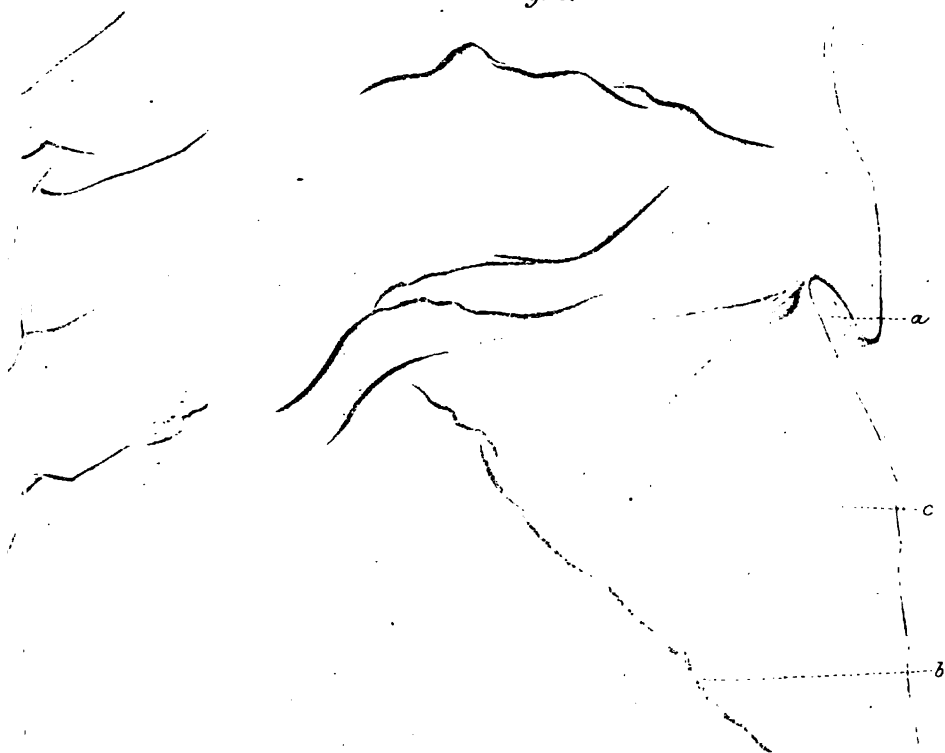
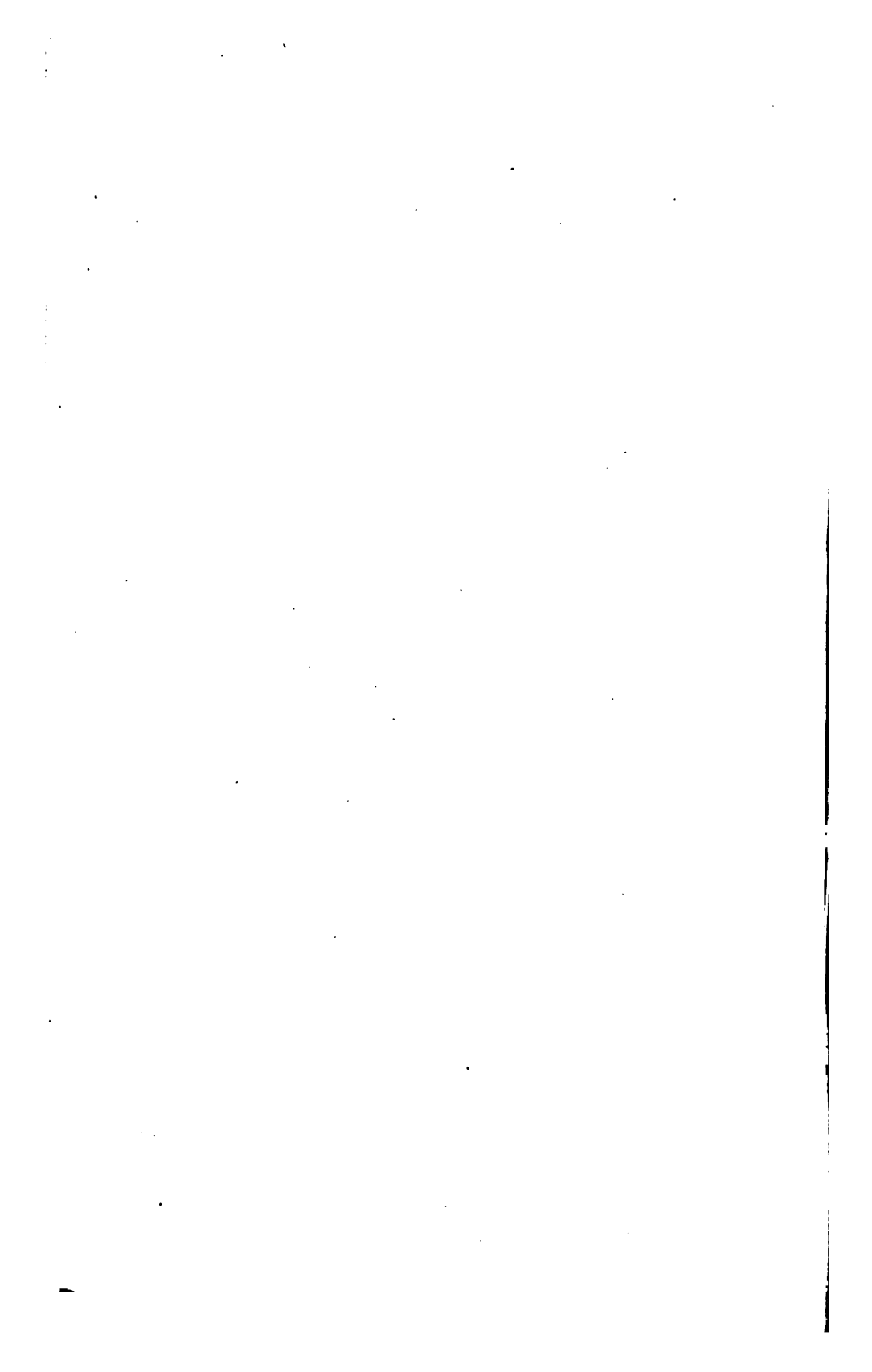




Fig. 6.





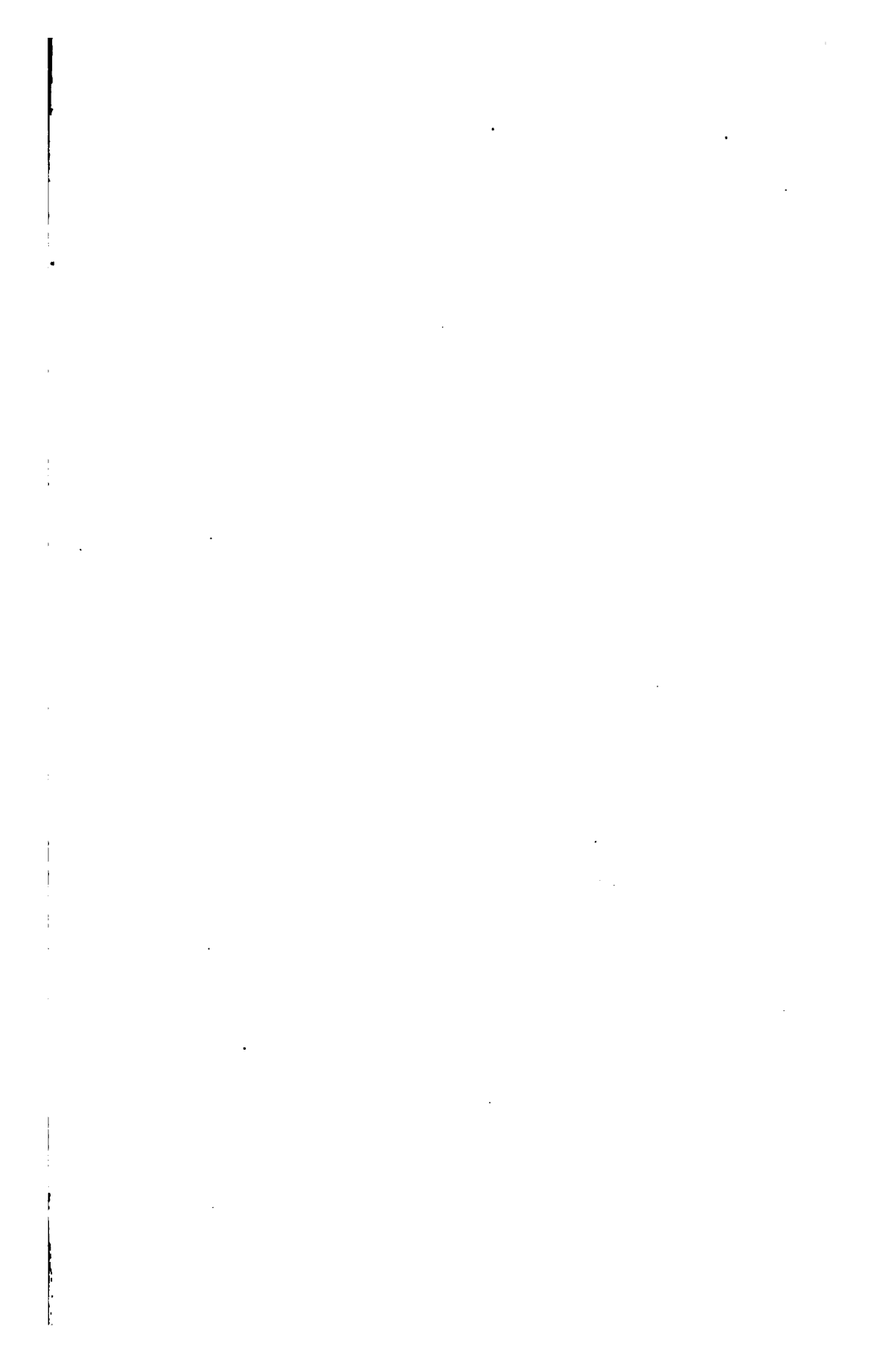


Fig. 7.

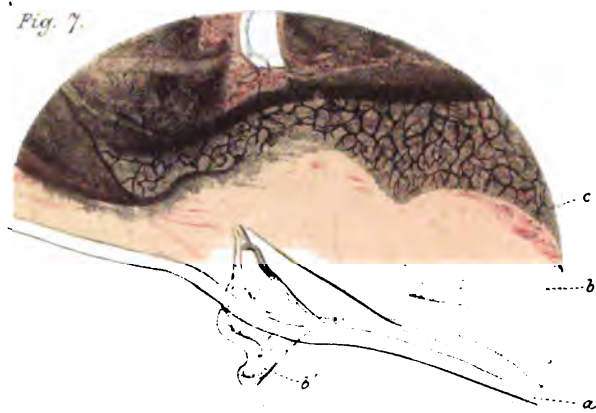


Fig. 8.

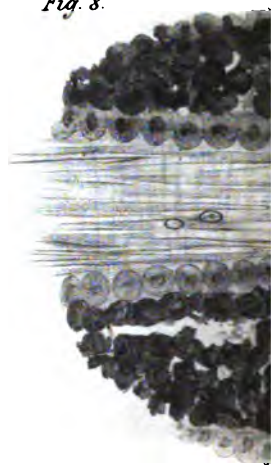


Fig. 9.

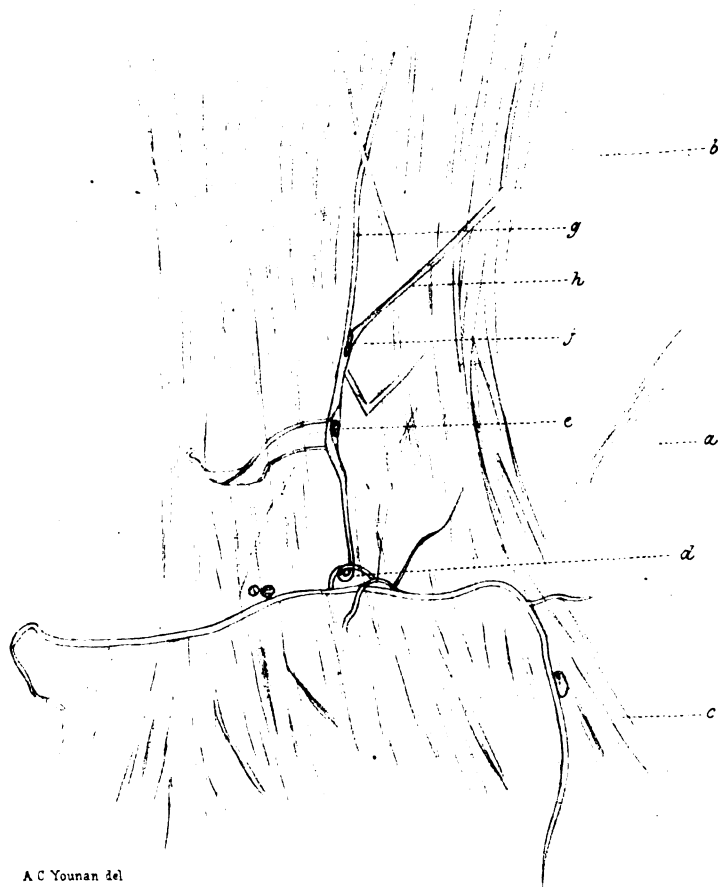


Fig. 10.



Fig. 11.

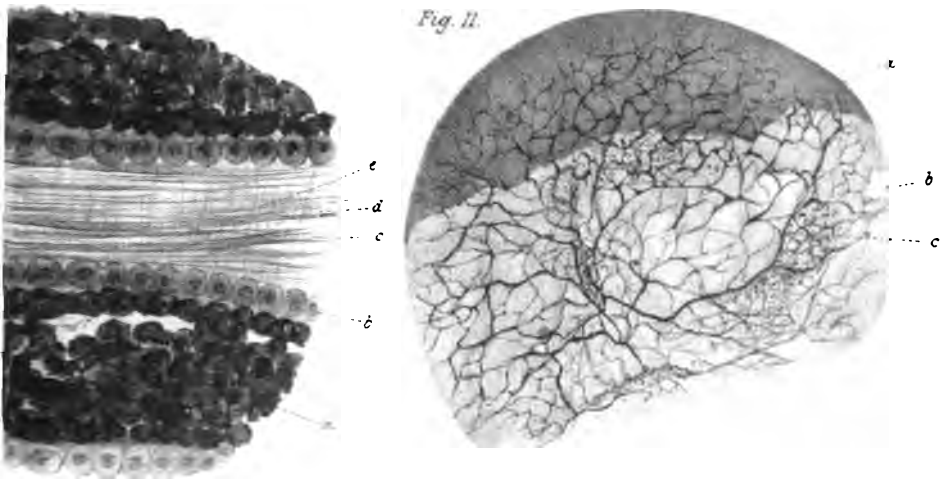
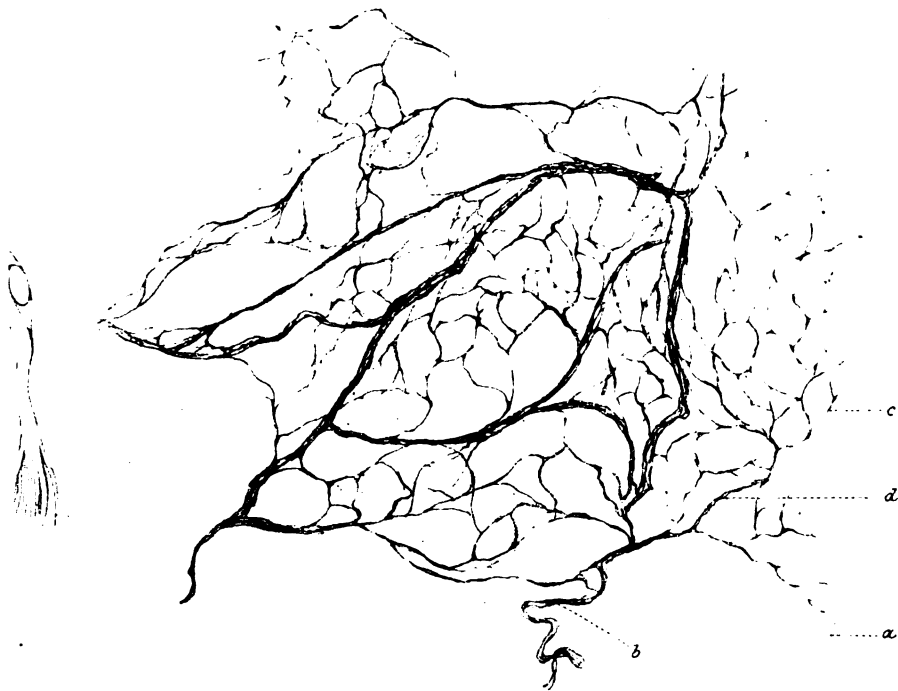
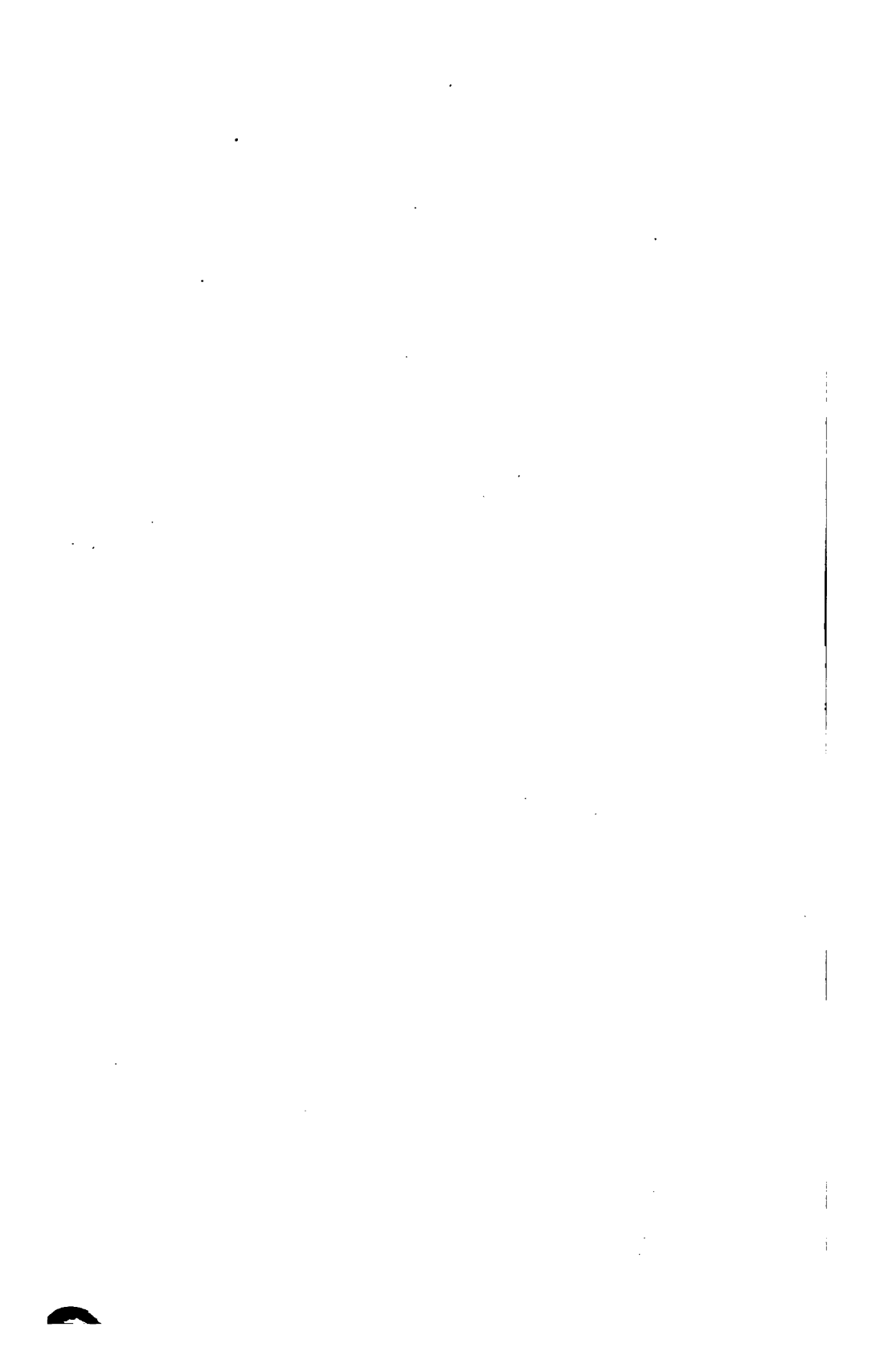


Fig. 12.





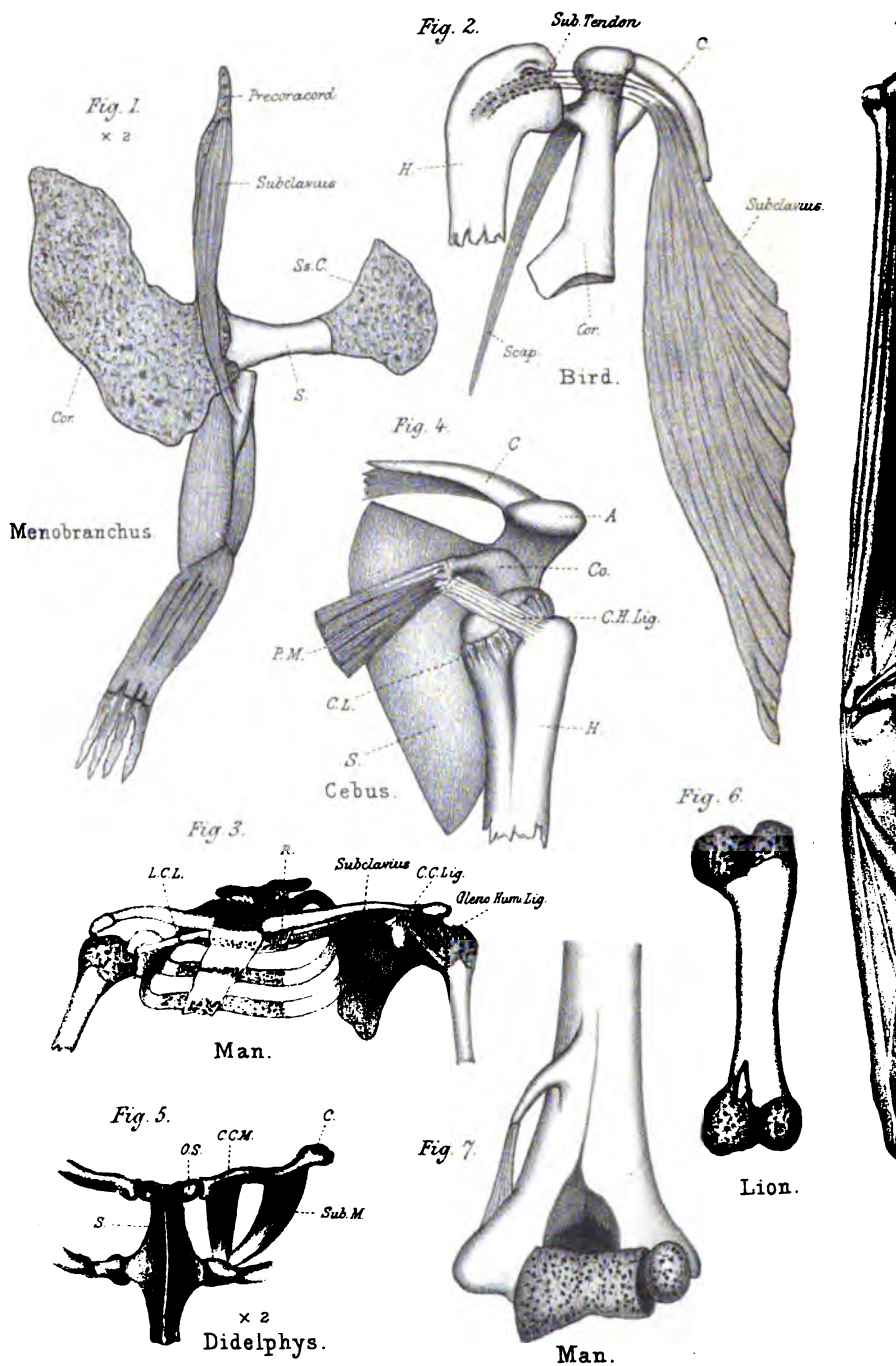
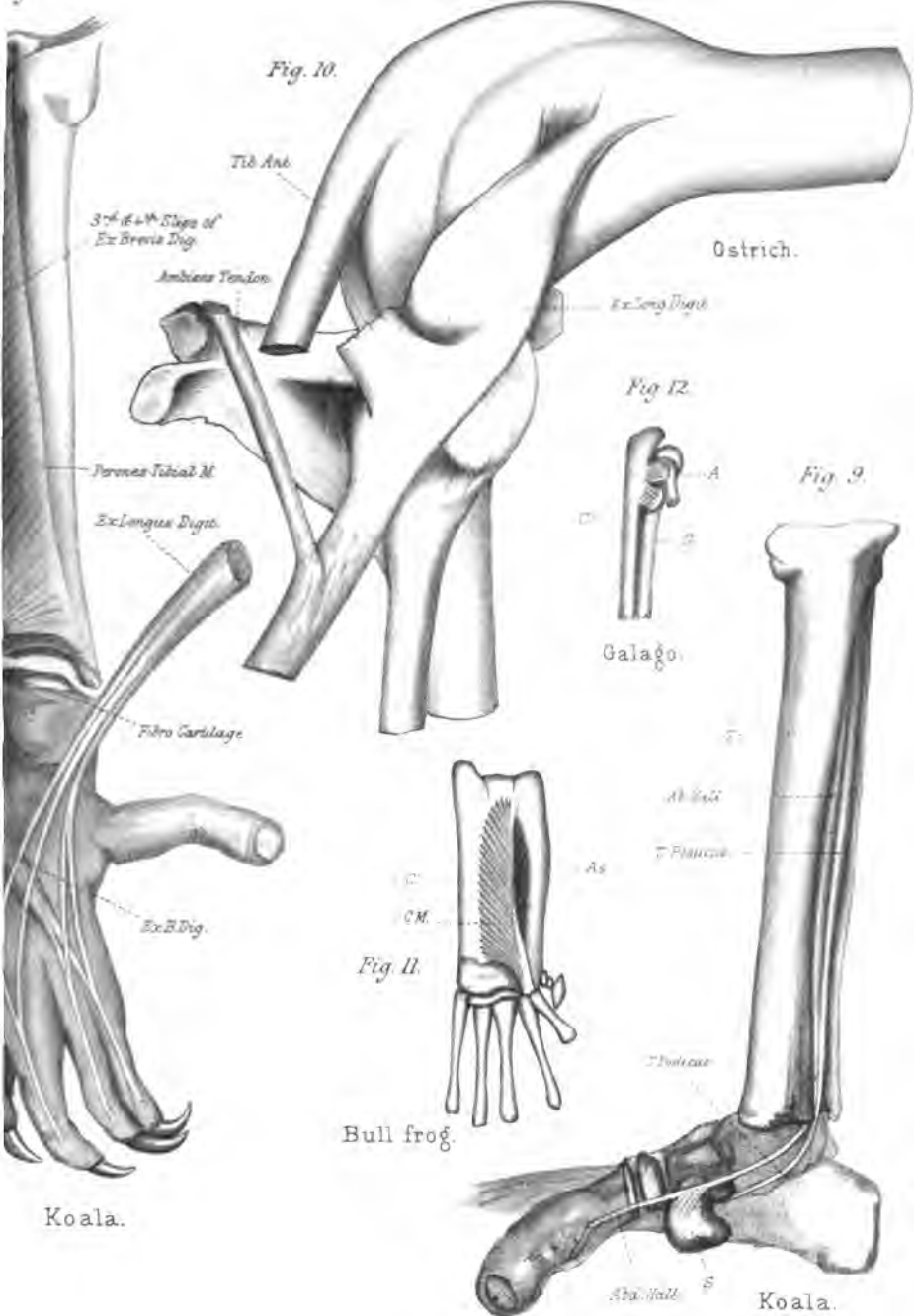


Fig. 8.



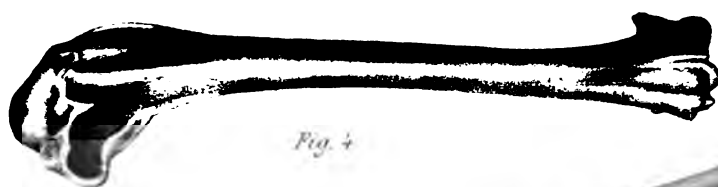


Fig. 4

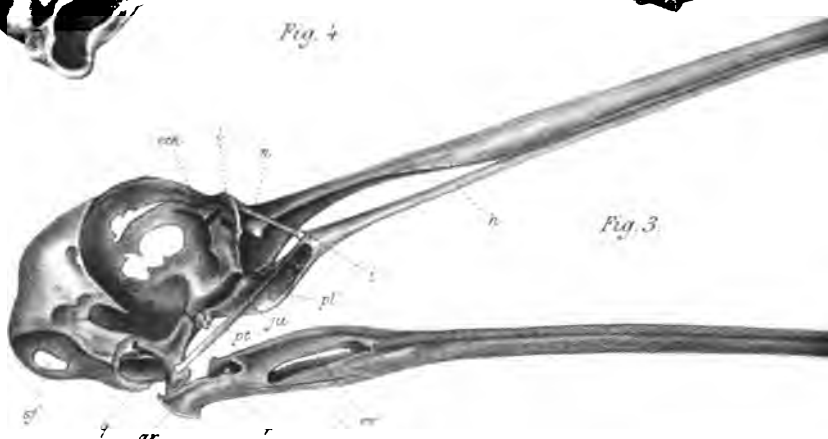


Fig. 3

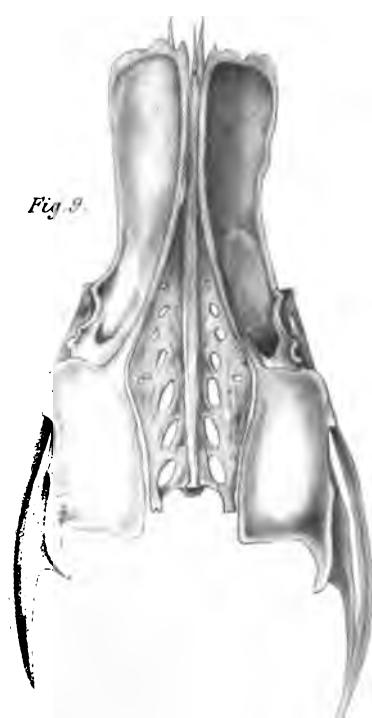


Fig. 9



Fig. 8



Fig. 7

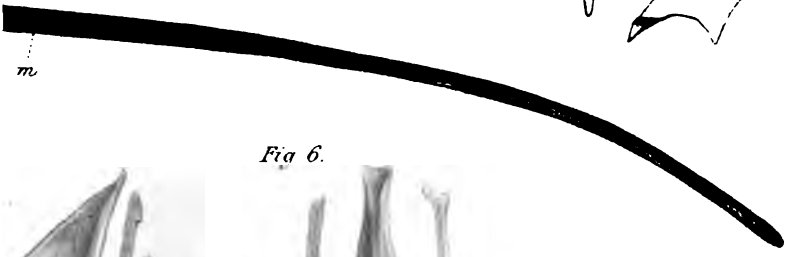
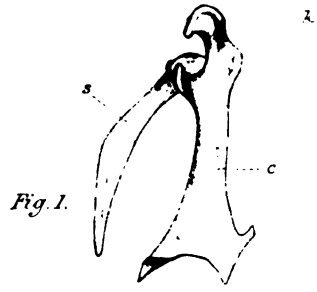
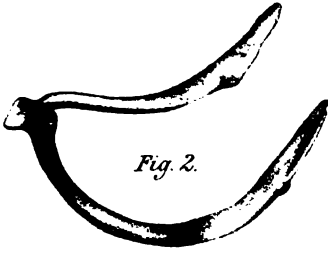
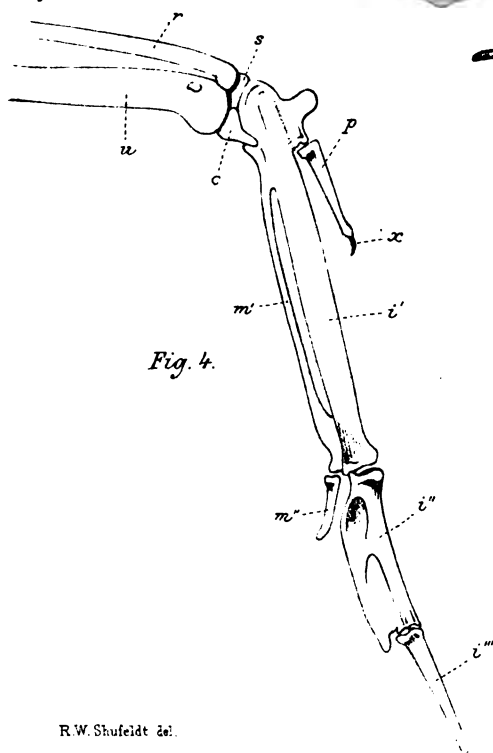
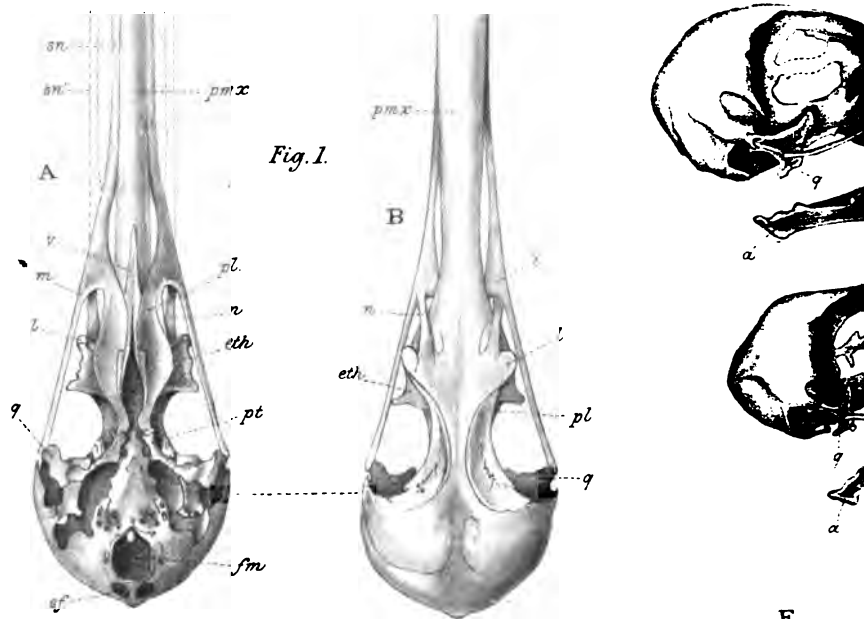


Fig. 6.





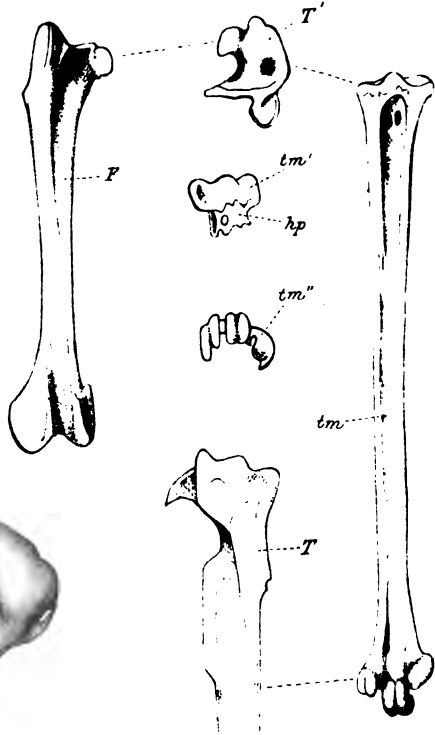
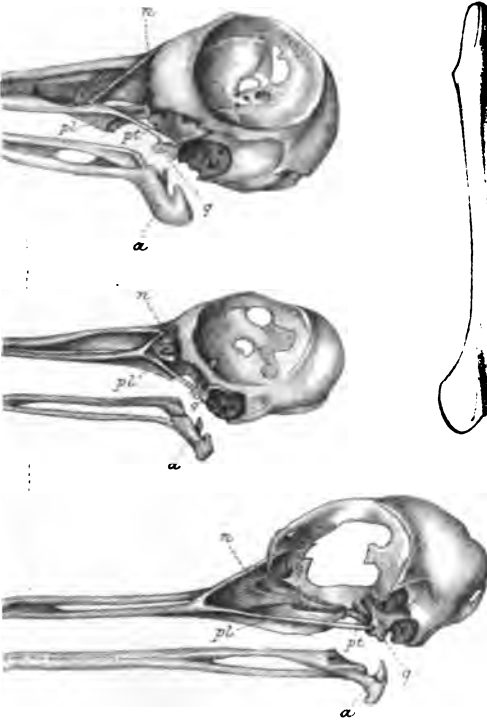
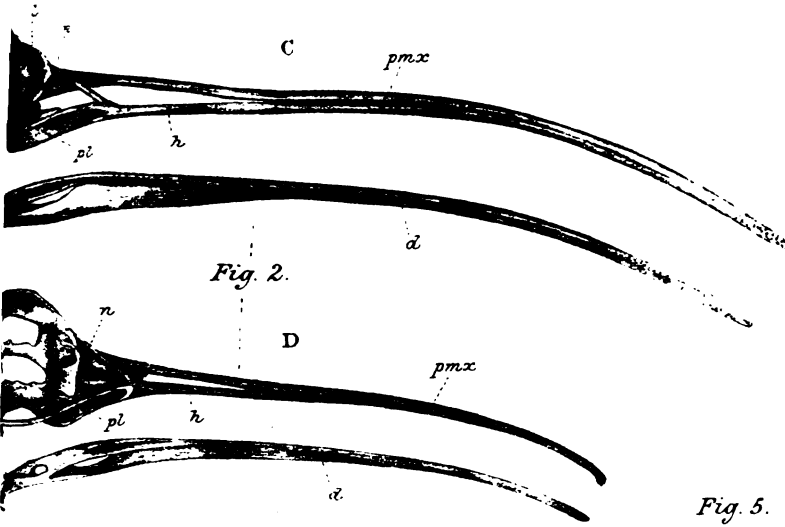


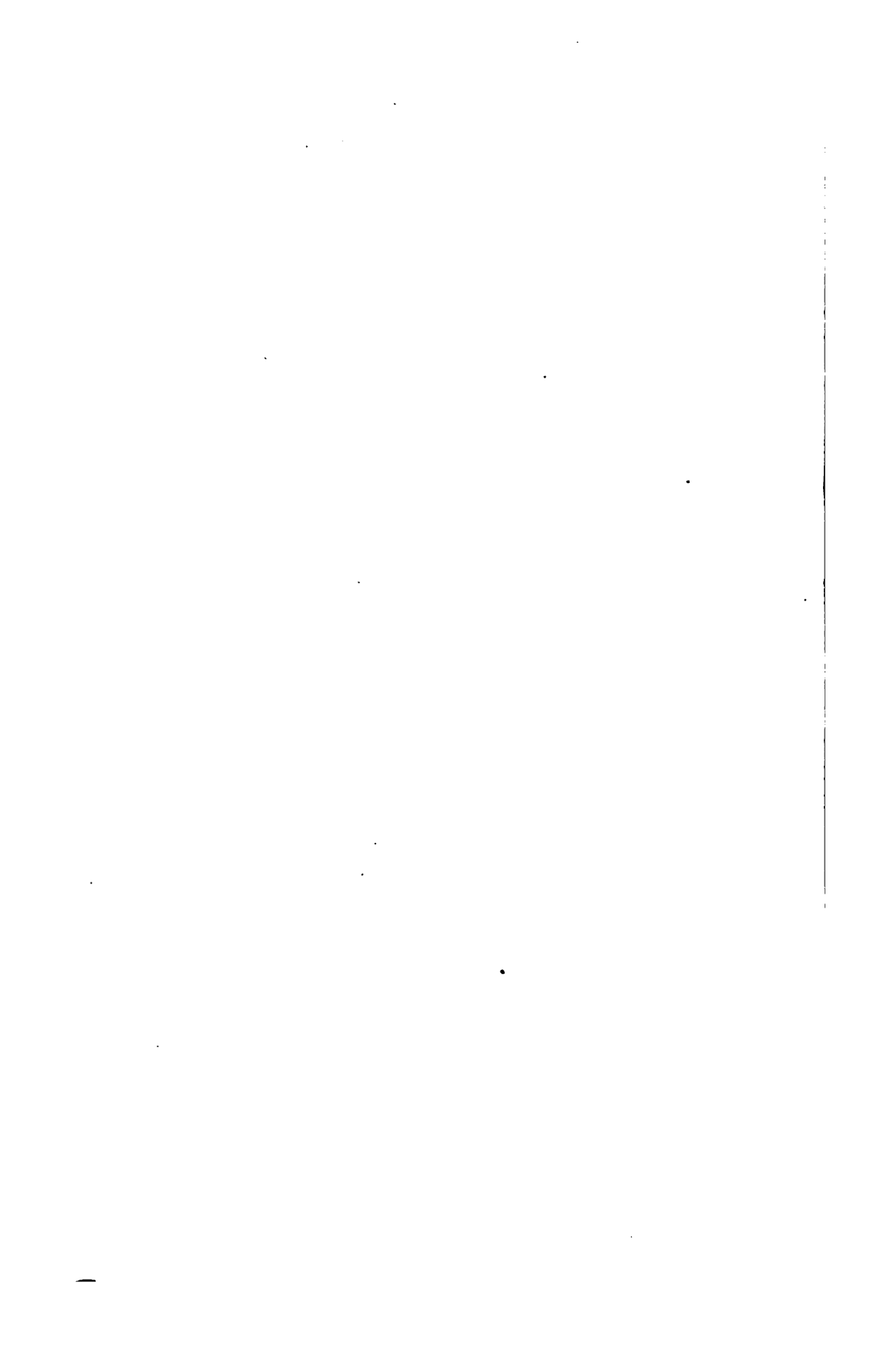


Fig. 2.

$\frac{1}{2}$ n. s.



Fig. 1.



Journal of Anatomy and Physiology.

DISEASES OF THE REPRODUCTIVE ORGANS IN
FROGS, BIRDS, AND MAMMALS. By J. BLAND
SUTTON, F.R.C.S., *Lecturer on Comparative Anatomy, and*
Senior Demonstrator of Anatomy, Middlesex Hospital
Medical School. (PLATE VIII.)

IN 1792 John Hunter wrote the following sentence:—"A spirit of inquiry concerning facts in natural history is diffused through all ranks of men, and those who cannot pursue it themselves, choosing to benefit by the industry of others, are eager to be informed of what is already known."

So little accurate knowledge is on record concerning the affections of the reproductive organs in animals, that the facts to be related in the following pages may not be unwelcome to those interested in the subject. Morbid conditions of the uterus will first occupy attention.

Flexions of the Uterus.

The first case encountered is recorded in the *Trans. Path. Soc.*, vol. xxxiv. p. 326, 1883. It was an example of retroflexion of the uterus which occurred in a West African baboon. The fundus was acutely retroflexed, and the posterior wall of the uterus had suffered atrophy. The animal had lived for some time in the Zoological Gardens. Since that case was published several examples of a similar character have come to hand.

The next case to be described was found in a Macaque monkey. The rectum in monkeys, as in the human foetus at birth, normally descends at the back of the pelvis lying exactly in the middle line. In this instance, however, it entered into

the pelvis on the right side; immediately above the anus it became distended, so as to force the uterus upwards and forwards. In this way the uterus became to a certain extent deprived of support from the pelvic organs, which resulted in its bending backwards in a condition of flexion, at the same time being considerably pushed to the left side.

The third example was found in a Bonnet monkey, *Macacus sinicus*, extremely distorted with rickets. The bones in all parts of the body were so soft, and yielded to pressure to such an extreme degree, that the opposite sides of the pelvis were almost in contact. This narrowing of the transverse diameter of the pelvis had caused the bladder and the uterus to be squeezed out of the pelvis to such an extent, that the upper part of the vagina and the neck of the uterus were found lying above the brim of the true pelvis. In this elevated position, deprived of support from the bladder and rectum, and at the mercy of the intestines, it is not surprising that the fundus of the uterus should have been doubled over in the condition of acute ante-flexion (Plate VIII. fig. 1).

In August last, a monkey, *Cercocercus collaris*, died, after a residence in the Gardens of four years. Every bone in the skeleton was softened with rickets, the pelvis being extremely affected. The uterus had been considerably elevated into the abdomen, as a result of the contraction of the transverse diameter of the pelvis, and had become flexed so acutely to the right side, that the fundus was found resting on the right psoas muscle. The uterus at the point of flexion was considerably narrowed, and the walls had atrophied (Plate VIII. fig. 3).

The ovaries were large and hard to the touch, and looked more like testicles than ovaries. On microscopic examination, they were found to be ovaries, with an amount of dense fibrous tissue in their structure; this accounts for their extreme hardness. The clitoris was of enormous size, surpassing in this respect the penis of a male. It is well known that in certain of the Cebidæ, particularly in *Ateles*, the clitoris does attain naturally enormous proportions, but in this particular case the clitoris far exceeded the average size it attains even in the spider monkey.

These two last cases of malposition of the uterus, as already

mentioned, were undoubtedly the result of rickety contraction of the pelvis. The following case will serve to illustrate the fact beyond question. A hybrid Macaque monkey, a male, was born in the Zoological Gardens. It was four months old, and died from pulmonary collapse, with rickety changes in every bone.

The pelvis was remarkably distorted on account of the extreme softness of the bones. The pelvic diameters were all shortened, and the cavity so encroached upon by the yielding walls, that the bladder, prostate, and vesiculæ seminales were squeezed into the abdomen; the apex of the prostate actually rested on the symphysis pubis. So narrow was the antero-posterior diameter at the brim, that the rectum and neck of the bladder were squeezed between the symphysis and the vertebral column. Figures 1, 2, and 3 on Plate VIII. represent three typical displacements of the uterus, viz., ante, retro, and lateral flexion.

In each of these cases the pelvis with its contained viscera has been represented, in order to avoid mistakes or exaggeration.

Leaving monkeys, some cases of flexions of the uterus occurring in other animals will now be described.

Two years ago the rare and pretty little animal *Hyomoschus* gave birth to a young one in the Zoological Gardens; some three months later it died. On examination, the uterus was found large and the fundus acutely anteflexed. Of course the question arose, May it not be the natural position of the uterus? Fortunately I had examined two specimens previously, and can state that their uteri were not in the position of this example.

Since obtaining this specimen, a large number of deer, gazelles, antelopes, &c., have been examined, and it is not uncommon to find a small degree of curvature existing at the fundus uteri, but it is in so slight a degree that the tonicity of the walls of the organ never allow the fundus to come in contact with the anterior wall of the uterus in health. An example has since occurred in a Mollucca deer, *Cervus molluccensis*. The animal died from the effects of some acute febrile disease.

The fundus of the uterus was so acutely anteflexed that it was in contact with the anterior wall of the organ, and had, by its pressure, caused atrophy. This malposition had evidently existed some long time, for dense fibrous bands stretched across the line of flexion and prevented the fundus returning to its nor-

mal position (fig. 4). These cases must prove beyond question that *flexions of the uterus occur in animals as well as in the human female*, but so far as can be ascertained the animals were in no way inconvenienced by the abnormal condition of the parts.

A very curious case of atrophy of the uterus occurred in a lioness. The uterus, Fallopian tubes, ovaries, and vagina were represented, but were of smaller size than the corresponding parts in a common cat. The animal was well nourished, and nothing reasonable can be advanced to explain the very small dimensions of the uterus and its appendages. It had never borne young ones.

Pyo-salpinx.

In June 1884, a kangaroo died in the Zoological Gardens from peritonitis. The abdomen was considerably distended, and the viscera matted together by adhesions of some old date. On examining the pelvic viscera, two swellings were found occupying the Fallopian tubes.

As the uterus and its appendages are somewhat complicated in the Marsupials, it will be advisable to give a short description of the parts as seen in the normal condition. In Plate VIII. fig. 5, is represented the vagina, which has passing off at its upper extremity two tubes, the lateral canals which open eventually into the uterine cavity (median canal), which below forms the median chamber ending usually in a cul-de-sac. From the upper end of this median chamber the orifices of the Fallopian tubes may be seen when the median canal is slit up. The ostia of the tubes present the usual fringed appearance, lying in close proximity to which may be seen the diminutive ovaries. The exact functions of the various parts of this complicated organ are not thoroughly understood by anatomists. The points about which information is required are these:—Do the young pass down the median canal, and establish an opening between the uterus and vagina, or do they come by way of the lateral canals? Or, are the lateral canals for the passage of semen only?

Messrs Lister and Fletcher published an admirable résumé of the question in the *Proc. Zool. Soc.*, 1881, entitled "The Vaginal Apparatus of the Macropodidæ." The following is a summary of their research:—

1. In the very early condition of the Macropididæ the median canal is closed.
2. In some genera, viz., *Macropus*, *Halmaturus*, *Petrogale* (*Dorcopsis* and *Dendrolagus*), an opening is formed in the median canal, to give passage to the young. This may take place in early life (*Halmaturus*), or not until the young are about to be produced (*Macropus*).
3. In the species *Macropus major*, however, this opening may or may not exist, and the young are transmitted either through the median or lateral canals.
4. In *Hypsiprymnus*, the median canal remains closed, and the young pass down the lateral canals, which differ in their structure from those species just quoted.

The normal anatomy and probable function of the various parts have been detailed, because they have an important bearing on the case before us. In all examples of marsupial uteri coming under my notice, a large quantity of mucus was present in all these passages. It seems to me that the very trifling amount of inflammation necessary to arrest the flow of secretion through the lateral canals, in cases where the median canal is imperforate, readily accounts for the distension of the Fallopian tubes. On opening these tubes in the present case, they were found filled with pus and caseous material. My opinion is, that this purulent matter gradually leaked into the peritoneal cavity through the abdominal openings of the Fallopian tubes, and had given rise to recurring attacks of peritonitis, which eventually proved fatal.

Diseases of the Ovaries and Oviducts.

Since Caspar F. Wolff, and the two princes among observers in biological science, Rathke and Johannes Müller, worked out the main points in the history of the remarkable series of changes which occur during the development of the mammalian reproductive organs, a sort of fascination seems to have surrounded this subject, to judge from the large number of talented observers in embryology who have been attracted to this question. Before entering into details concerning the pathology of these organs, it will be well to trace briefly the chief points in the formation of the various structures, for unless a clear

conception be formed of the development of the parts, some misunderstanding may arise. Later researches, particularly those of Semper and Balfour on the Development of Elasmobranch Fishes, enable us to recognise three typical parts to these organs, each of which agree fundamentally, in that they consist of two parts, a glandular mass with its correlated duct. These

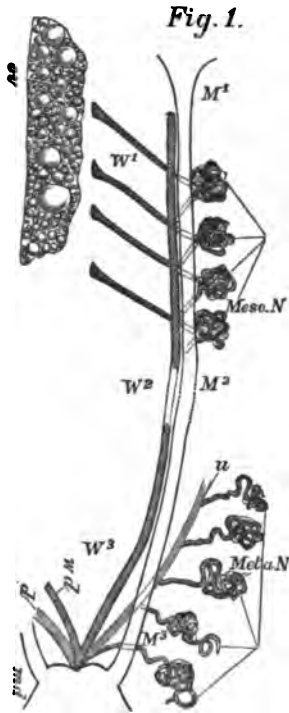


Diagram to show the relation of the Genital Ducts in the Embryo
(*vide text*), after Balfour.

ducts, in the early embryo, open posteriorly into the cloaca. The three segments may be thus classified :—

1. A glandular mass known as the Pronephros or Head Kidney. Its associated duct is known as the Müllerian Duct.
2. The Mesonephros or Wolffian body, in relation with the cloaca by means of the segmental or Wolffian Duct.

The gland is brought into connection with its duct by means of the segmental tubes (*vide* fig. 1).

3. The Metanephros or Kidney having for its excretory duct the ureter. This will not further concern us.

A glance at fig. 1 (text) will help to make the description more intelligible. M^1 , M^2 , M^3 , indicate Müller's Duct. W^1 , W^2 , W^3 , the Wolffian or Segmental Duct, with its transverse tubules and the Mesonephros; u , refers to the ureter with the Metanephros.

Of these ducts we are concerned with two only, the Wolffian and the Müllerian.

These ducts undergo a series of remarkable changes, which with the help of a figure may be thus described :—

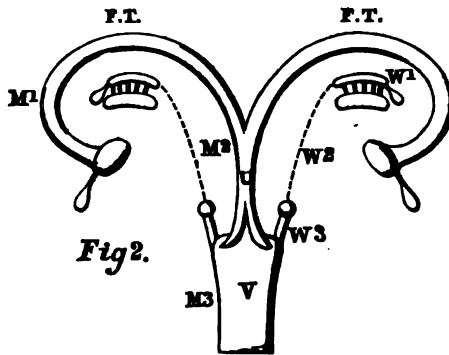


Diagram to show the metamorphosis of the Müllerian and Wolffian Ducts in the Female (*vide* text).

1. *The Müllerian Duct.*—In the female this duct develops into an oviducal passage in fish, amphibians, reptiles, and birds, but into an uterus in mammals. The formation of the uterus and its essential parts takes place after this manner.

The Müllerian duct may be conceived as being made up of three parts :—

The upper third becomes the Fallopian tube, the funnel-shaped opening communicating with the peritoneal cavity, and supports a tiny cyst, commonly known as the “Hydatid of Morgagni,” but for pathological, if not for anatomical, purposes would be much better termed the “Müllerian cyst.”

The middle portion of each duct fuse together, and form the

fundus, body, and neck of the uterus, whilst the lower third of the Müllerian ducts join together and form a vagina. Such is the commonest arrangement.

In the accompanying woodcut (fig. 2, text), the letters M¹, M², and M³ refer to the three portions of the duct after the metamorphosis.

2. *The Segmental (Wolffian) Duct.*—This duct and its associated tubules has no function in the female, but its atrophied remains are often to be detected. Like the preceding duct, it may for the purpose of convenient description be divided into thirds.

The upper division, with the segmental tubes, may be detected lying above the ovaries in the folds of the broad ligament, and is commonly referred to as the "Organ of Rosenmüller," or better the "Parovarium."

The middle portion usually atrophies, whilst the third portion often forms a narrow tube lying in the broad ligament, and running towards the upper part of the vagina is recognised as the duct of Gärtner (*vide* fig. 2, W¹, W², W³).

The Parovarium (Organ of Rosenmüller).

Apart from its anatomical interest, great importance attaches itself to this structure, on account of the relation it bears to cystic formations occurring in the neighbourhood of the broad ligament.

The parovarium may be easily seen by holding the mesosalpinx between the eye and the light, then a series of tubules will come into view, radiating from the ovary to join a longitudinal tube situated at right angles to them. Although these tubules converge at their ovarian end, nevertheless they remain distinct; they are lined with epithelium, and each tubule ends blindly. In form and disposition they recall exactly the arrangement of the vasa efferentia and commencement of the epididymis in the male—indeed it is these ducts which in man constitute that portion of the excretory apparatus of the testicle.

It has been clearly proved by many observers, that in the human female the ducts in question are very liable to become distended with fluid, so as to form pedunculated cysts, usually

of small size, but now and then they assume disagreeable proportions. The cysts may arise either by distension of the vertical tubes or by dilatation of the longitudinal one.

Examples of cysts arising after this manner will be fully considered later on.

Gärtner's Duct.

This duct, which was first detected in cows and swine by Gärtner in the year 1822 is occasionally present in the human female, and may be detected as a tube in the broad ligament of the uterus, but lower in its course, becomes incorporated with the walls of the vagina, occasionally opening on the mucous surface of that tube.¹ This functionless duct may become the seat of cystic formations.

The clearest and best described example of a cyst originating in this duct, that I am aware of, will be found in Virchow's *Archiv für Pathologische Anatomie* (Band xcvi. Heft 1, s. 100). Carl Rieder there contributes a paper of considerable interest, entitled "Ueber die Gärtner'schen (Wolf'schen) Kanäle beim Menschlichen Weibe," wherein the literature and frequency of persistence of this structure in various animals, including man, is ably discussed. Not the least interesting point in the paper is the description of a preparation from the collection of the Pathological Institute at Basel, of a case of multiple cysts in the walls of the vagina of a woman, aged twenty-eight years, who died in the fifth month of pregnancy. Rieder's object is to prove, and this he does very conclusively, that the cysts in question were the result of abnormal dilatation of Gärtner's ducts.

The Müllerian Ducts in Male Frogs and Toads.

For some time past I have devoted considerable attention to cases of ovarian disease occurring in wild and other animals; very many cases of considerable interest have come under notice in the course of my work at the Zoological Gardens, and many others have been derived from various sources.

At the outset attention is invited to certain abnormal conditions of the Müllerian duct in male frogs and toads which will

¹ The opening of the ducts known as Skene's tubes must not be confounded with Gärtner's ducts. The former are associated with two glands lying in the wall of the vagina near where Gärtner's ducts usually terminate.

go to show *that it is a condition exceedingly common for functionless ducts to become cystic in animals other than man.*

In the male of the common frog, *Rana temporaria*, the generative organs have the disposition exhibited in Plate VIII fig. 6a. They may be thus described:—On either side is seen the testis, surmounted by the corpus adiposum, with *u*, the duct which functions as the vas deferens as well as a ureter: *v.s.* are the vesiculæ seminales with the Müllerian ducts, which, in the female become enlarged to function as oviducts, are here seen as delicate thin streaks ascending in the peritoneum, from the summit of the vesiculæ to the root of the lungs.

Although the vesiculæ seminales in the frog give one the impression that they are dilatations of the Müllerian duct, nevertheless, as a matter of fact, they belong to the Wolffian duct; but their mode of origin has no bearing on the subject of this paper, and will not be considered any farther.

In the toad *Bufo vulgaris*, the most important features are these—

Between the testis and the fat body is a singular structure, called in honour of its discoverer "Bidder's Organ." This organ, according to the most recent researches, is nothing more or less than a rudimentary ovary, and as such seems to exercise a very remarkable influence on the degree of development of Müller's duct in the male toad.

In frogs, as we have seen, the Müllerian duct in the male is scarcely perceptible, but now and then it happens that a frog sometimes develops a "Bidder's organ," or ovary in conjunction with the testis, forming what amounts to an ovo-testis, and singularly enough the Müllerian duct or oviduct then assumes some considerable size. For the purpose of testing this question in toads, more than two hundred and fifty have been examined. It would appear that, as a rule, *the amount of development of these ducts is in direct proportion to the size of "Bidder's organ."* But the point which concerns us most as pathologists is, that it is exceedingly common to find a *cyst* developed in these rudimentary oviducts in the toads. A characteristic example of the cystic condition is shown in Plate VIII. fig. 6, so that these batrachians afford ready and indisputable examples of *functionless ducts becoming cystic in parts of their course.*

Cysts in Birds.

In birds, as in frogs and toads, upon the Müllerian ducts devolve the duty of safely conveying the ova from the peritoneal cavity to the exterior. In the early chick both Müllerian ducts and ovaries are equally developed, but in the mature bird the left duct and ovary alone persist, the right having atrophied. In the majority of birds no trace of the right duct remains, except a small tube, about an inch long, attached to the right side of the cloaca, often bearing on its summit a small nodule of fat, the degenerated representative of the remaining portion of the duct.

The persistent left oviduct may be thus described:—

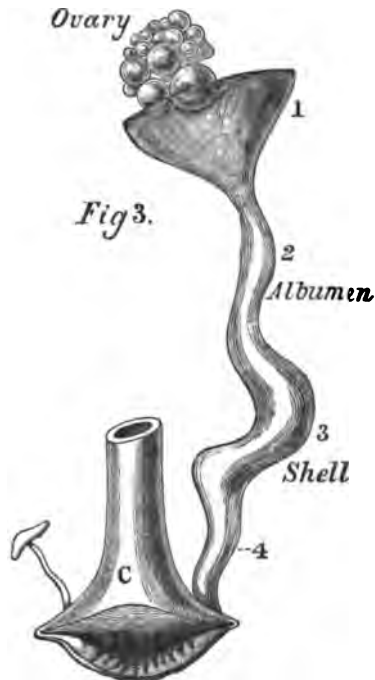
In the quiescent state the duct is nearly straight, but during the breeding season it undergoes considerable enlargement and becomes convoluted. It is maintained in position by a fold of the peritoneum, and extends from the cloaca posteriorly, and terminates by opening anteriorly into the peritoneal cavity just below the ovary, by a funnel-shaped termination known as the infundibulum. It will be convenient to describe this tube as made up of four parts.

- 1st. The dilated infundibulum, with its thin delicate walls; this is followed by the
- 2nd portion, long and tubular, constituting the oviduct proper; this opens by a narrow constricted portion into the
- 3rd, or uterine part, which is much larger than the other divisions of the tube, and possesses fairly thick muscular walls.
- 4th. This is somewhat narrow, and leads from the uterine portion into the cloaca. The oviduct is lined throughout with mucous membrane covered by ciliated epithelium. In some parts of the tube the mucous membrane is thrown into spiral ridges.

The various portions of the oviduct are indicated in fig. 3 (text).

When the ovum escapes from its follicle in the ovary, it as a rule falls into the infundibulum of the oviduct, passing thence into the second and third portions of the tube; during its passage through the second portion or oviduct proper, it acquires a layer

of albumen, and the spiral motion given to the egg by the ridges in the mucous membrane as it descends, form the chalazæ (because these bands contain little white spots, hence *χαλαζαί*, hailstones), or twisted bands formed of denser albumen attached to the two opposite portions of the yolk; later on the chalazæ are also enveloped in albumen. In the third portion of the tube the shell is formed. The mucous membrane of this, the uterine portion, contains some follicular glands which secrete a thick



Reproductive Organs of the Female Bird (*vide text*).

white fluid; this coats the egg, and serves as a nidus for the inorganic particles which ultimately form the shell.

The transit probably occupies on an average twenty to twenty-four hours, of which more than three-fourths are spent in the uterine portion of the oviduct.

In the first place, some abnormal conditions of the rudimentary right oviduct will demand attention. From what has been

stated in respect of frogs and toads, it will of course not surprise us to find that the remains of the Müllerian duct of the right side should occasionally be found in a cystic condition. Such is indeed the case. Whilst engaged in making a *post-mortem* examination on an old barn-door hen that had died paraplegic, in consequence of myelitis, it was observed that the rudimentary right oviduct was present, not as a narrow tube about an inch in length, but as a cyst the size of a gooseberry, filled with serum-coloured fluid, whilst attached to the upper extremity by an exceedingly narrow pedicle was a second cyst of the size of a cherry, also containing fluid of similar character.

That such cysts may be a source of danger to a bird, who is so unfortunate as to possess them, is well illustrated in a case now to be related.

A black-neck swan died from the effects of acute peritonitis, the cause of which for a time was somewhat obscure. When examining the cloaca, a distended tube about an inch long, the remnant of the right oviduct, was observed; attached to its summit was the narrow pedicle of a cyst, the main portion of which could not be found. It would seem that in this case the cyst had become detached, or its contents extravasated into the peritoneal cavity, producing peritonitis with a fatal result. The viscera of the bird were in other respects healthy.

In Plate VIII. fig. 7, is represented the cloaca of a hen with the left oviduct cut short. On the right side may be seen a rudiment of the right oviduct, which, in its upper part, is of the usual size of this remnant when present. In its lower part, however, it affords an example of a very early stage of the cystic condition. The bird was old, and had ceased to lay eggs.

During the present year, whilst on a visit to my friend Mr Edward Swan of Middlesborough, who, being much interested in questions of comparative pathology, kindly placed some of his fowls at my disposal for purposes of dissection. One of these birds afforded me the best example of an oviducal cyst I have yet encountered.

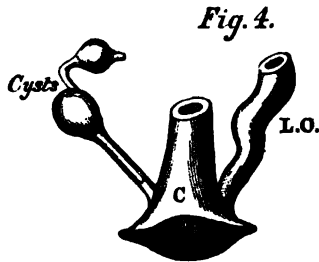
The bird was a Spanish hen, and on opening the abdomen we found lying on the right side of the cloaca a cyst measuring 3 inches in length, and supporting on its summit, by a narrow pedicle, a second but much smaller cyst. Its general appearance

and shape may be inferred from fig. 4 (text). The walls of the cysts were exceedingly delicate, transparent, and enclosed a quantity of thin watery liquid, in which small particles of coagulated albumen floated. This was also an undoubted example of a dilated rudimentary right oviduct.

The Teratological Series in the Museum of College of Surgeon's possesses an example of a cystic oviduct in a bird. It is thus described in the Catalogue:—

"The sacrum of a young fowl with the right oviduct persistent. It forms a large thin-walled cyst, which was distended with air. The left oviduct was normal; it has been removed, but its orifice is indicated by a bristle. The specimen was presented by Mr W. B. Tegetmeier."

A careful examination of this specimen shows, that in this



Cystic right Oviduct in a Hen, reduced to $\frac{1}{4}$ th natural size
(*vide text*).

case, as in the preceding ones, the structure in question is a remainder of the right oviduct, which has become distended so as to form a cyst.

The same series contains also an admirable example of the oviduct with the ovary of a hen, which during life laid eggs about the size of a pigeon's, consisting exclusively of albumen, covered by a very perfect shell. The oviduct was too small to transmit the yolks, for when the abdomen was opened, the peritoneal cavity was found to be full of the yellow fluid contents of the yolks, which had escaped. It would appear that as each yolk was matured, it fell into the abdomen, and was ultimately absorbed, whilst the oviduct poured out albumen, and formed a shell, as it would if the yolk had fallen into the oviduct. The

hen when killed was apparently healthy. Specimens of the eggs are preserved in the Museum; they consist of normal albumen enclosed in a small but well-formed shell. This specimen throws important light on a circumstance which puzzled me extremely as a boy. Most persons who have visited poultry yards must have noticed that it is extremely common for pullets to lay small eggs without yolks, and as boys the explanation was, "that the pullet had not yet acquired the art of laying properly!"

However, it now and then happens that a hen in "full lay" will deposit an egg of small size without a yolk. Shrewd country people explain this by saying, "that the preceding egg contained two yolks,"—a subtile explanation truly. It is clear enough, at least to me, that in these cases the ovum either fails to fall into the oviduct, or if it does reach that duct it may, by some accident, be tossed out, and falling into the peritoneal cavity, become absorbed. With regard to mammals, it is well known that the impregnated ovum does now and then miss the Fallopian tube, and in other instances reaching that duct, fails to pass into the uterus, both conditions coming under the term extra-uterine foetation. In all cases of extra-uterine gestation, the mucous membrane of the uterus undergoes hypertrophy, in the same way that it would, if the impregnated ovum had tumbled into its cavity, as in the course of events in normal pregnancy. Remembering that the shell, with its membrane and albumen, correspond in a great measure to the decidua of mammals, at any rate the greater part of the decidua, like the albumen and shell of the bird's egg, are the direct result of the activity of the uterus and uterine portion of the oviduct respectively, we have in these two instances parallel circumstances, viz., the presence of a shed, and probably impregnated ovum, exerting an influence on the uterus, though it be at some distance from the part; hence this is clear, it is not merely actual contact of the ovum with the uterine mucous membrane that brings about the formation of the uterine decidua, but some "subtile influence" we know not of.

It may not be out of place, or inconsistent with the general tenor of this article, to give some further examples of this 'subtile influence' on the general economy of birds.

Effects of Ovarian Disease on Birds.

John Hunter has placed on record some interesting facts bearing on this question, in his account "Of an Extraordinary Pheasant." It appears that now and then a hen pheasant is seen with the feathers of a cock; the animal does not breed, and its spurs do not grow. Dr Pitcairn received a bird of this kind from Sir Thomas Harris, and showed it to Sir Joseph Banks and Dr Solander; Hunter being present, examined the bird, and found that it possessed *two ovaries and oviducts*.

Among the other cases instanced by Hunter, the following is the most remarkable:—

Lady Tynte had a favourite pyed pea-hen which had produced chickens eight several times. Having moulted when about eleven years old, the lady and family were astonished by her displaying the feathers peculiar to the other sex, and appeared like a pyed *peacock*. In this process the tail, which became like that of a cock, first made its appearance after moulting; and in the following year, having moulted again, produced similar feathers. In the third year she did the same; and, in addition had spurs resembling those of a cock. She never bred after this change in her plumage, and died in the following winter during the hard frost, in the year 1775–6.

These facts are extremely interesting, for as Hunter points out, we find similar changes taking place in the human species; for the increase of hair observable on the face of many women in advanced life, is an approach towards the beard which is one of the most distinguishing secondary properties of man.

When females pass the child-bearing period of life, that is when the ovaries become functionless, they often assume more or less masculine characters.

The assumption by the female of feathers somewhat like those of the male bird, is a fact, so far as I can ascertain, first placed on record by John Hunter, and it has caused other naturalists to inquire into the question. Yarrell communicated a paper to the *Phil. Trans.*, 1827, on the subject; the following is the pith of his researches:—

He had an opportunity of examining seven hen pheasants, in plumage more or less resembling the male, and in all of which

the sexual organs were diseased, but with some variation as to extent. The ovary was contracted in size, of a purple colour and hard to the touch. The oviduct was diseased throughout its whole length.

Some cases are also quoted at length to show that the change in the sexual organs precedes the alteration in the plumage. That this change in the feathers is secondary to affections of the sexual organs the following facts bear testimony.

The poultry breeder learns, from the attempts of the young bird to crow, that the testes have enlarged sufficiently for him to perform castration. After the operation is performed, the bird never crows again. The combs, gills, and spurs remain short and blunted, and the feathers put on an appearance intermediate to those of the cock and hen.

The operation on the female bird consists in making a small incision through the skin on the flank of the left side, and so on until the oviduct is reached, and a piece cut away. After the operation the ova do not enlarge, and the hen makes an attempt to imitate the crow of a cock, there is an increase in the size of the comb, and a spur or spurs shoot out, but remain short and blunt. The feathers also undergo a change in colour.

Another peculiar feature in these unsexed hens is the singular shape of the lower part of the back,—due to the want of enlargement of the bones observed in all true females, by which they attain a breadth of the pelvis sufficient to allow the eggs to pass.

It is well known that the beautiful plumage which many birds assume in the spring is coincident with the dilatation of their sexual organs under the influence of the genial weather.

Yarrell entered carefully into the matter of disease of the sexual organs being a cause of this singular change of plumage, because Dr Butter, in the *Wernerian Transactions*, vol. iii., states that all hen birds would acquire this change of dress if they lived to be old enough; this of course is erroneous, *the change coming on in old birds is the result of the cessation of ovarian activity.*¹

¹ Prof. Turner has described, in *Proc. Roy. Phys. Soc. Edin.*, vol. iii. p. 297, 1862-66, a bantam hen, aged 18, which had assumed male plumage and developed a well-formed spur on the left leg. The ovarium was shrivelled and the ova atrophied. Numerous pea-like bodies, containing a yelk-like fat, were either lying loose in the abdominal cavity or attached by short pedicles to the peritoneal lining. They seemed to be aborted or degenerated ova.

Darwin refers to the fact in the *Descent of Man*, as though it were well recognised. After writing concerning the females of certain species of birds which, in the first year or two after they are hatched, differ in colour from the males, nevertheless later in life naturally acquire the coloration &c., of the male (*Falco peregrinus*, *Bombycilla carolinensis*, *Palæornis javanicus*), he says—

These cases must not be confounded with those where diseased or old females abnormally develop masculine characters.¹

Dr Larcher has published, in the *Journal de l'Anatomie et de la Physiologie*, Nov. 1873, an article on "Les Affections des Parties Génitales Femelles chez les Oiseaux," where, among other conditions, this relation between feathers and sexual organs is discussed and further evidence offered, so that the phenomenon in question is beyond doubt.

The most remarkable instance of change of plumage in a hen bird, that has come under my own notice, concerns a female golden pheasant now living in the Pheasants' Aviary in the Zoological Gardens, London. A pair of birds, male and female, were presented to the Society by Sir H. W. Tyler, M.P., but the hen bird presents all the resplendent dress of the male bird, even to a slight yellow coloration on the legs. On comparing her with the male bird, the following differences only can be perceived:—The eye is perfectly dark, whereas in the male bird a ring of white encircles the iris, and the colour of the plumage is not quite so brilliant as in the male, and she has no spurs. Mr Misselbrook, the head-keeper at the Gardens, informs me that the bird has undergone two moults. In spite of the deceit of feathers, the male bird lives with her quite happily, and they have not been seen to fight. On several occasions I have seen a male bird in the next cage, who was companionless, making overtures towards his neighbour's hen in spite of the assumed plumage.

¹ In cases of hermaphroditism occurring among Lepidoptera one side presents the characteristics of the male, the other half those of the female. Also, the female may assume the coloration of the male where normally the colour of the two sexes widely differs (J. Jenner Weir, *Entomologist*, Aug. 1888).

Ovarian Cysts in Mares.

We must now pass on to consider some cases of cystic disease of the ovaries occurring in mares.

Some years ago a friend gave me for anatomical purposes an old carriage mare; during the dissection, it was observed that both ovaries were enlarged to the size of an orange (the normal size equals a walnut), their increased dimensions resulting from the presence of several cysts.

The specimen remained in spirit for three or four years.

Last winter I investigated the matter.

The ovaries of fifty mares, chosen promiscuously, were collected; but most of the animals were killed on account of their age, none from disease. Of this number two-thirds presented me with cystic ovaries. Each affected ovary was found to contain from two to six cysts, varying in size from a grape to an orange. Plate. VIII. fig. 8, may be taken as a fair illustration of this condition.

My first impression was that these cysts were really enlarged Graafian follicles, and a few doubtless do arise from this source, but the majority have an origin of a very different character.

When describing the parovarium, attention was drawn to the fact that the tubules composing that organ converged towards the ovary. If a little care be exercised these tubules may, in very young subjects, be traced for a short distance into the substance of the ovaries.

The *Trans. Path. Soc.*, vol. xxxii., 1881, is enriched by a paper from Mr Alban Doran concerning some proliferating cysts which he found in the ovary of a seven months' foetus. In this case Mr Doran clearly and ably associates these cysts with remains of the Wolffian bodies and tubules well known to occupy this region.

After reading Mr Doran's paper, I kept careful watch among the many foetuses dissected at the Middlesex Hospital for similar cases, and have been rewarded by finding an excellent example of a cystic ovary in a foetus born at full time. In this case the cyst was not embedded in the substance of the ovary, but was at once visible on examining the parts, as a distinct projection, on the outer surface of that organ. The cyst was of the size

of a split pea, and contained clear fluid; careful examination of the specimen seems to show that it was the result of abnormal distension of a parovarium tubule where it joined the ovary.

Returning to mares, the following points are worthy of notice:—

1. The cysts in question are most common in old mares, and at a time when they cease to propagate.
2. The majority of the cysts occupy the meso-salpinx, and are unconnected with the ovary.
3. Those cysts which encroach upon the ovary, do so by their pressure causing absorption of the ovarian tissue.

Several instances have come under my notice where nearly the whole of the ovary has been absorbed by the pressure of such cysts.

If this view as to the origin of these cysts is correct, the following question naturally arises, Why should these tubules remain quiescent throughout the youth of the animal, when growth is in full vigour, to attain unnatural dimensions in old age?

The same question might be put with equal fairness to the case of the prostate of man, and the following answer applies with equal force to both cases.

In the ovary of the mare, as with the prostate of man, there is a great tendency for the veins to dilate and become surcharged with blood. In the case of the mare the plexus is of remarkable size, and the individual branches of the veins are very large.

Venous stagnation leads to dropsy, and to hypertrophy very often, hence it is not very unreasonable to suppose that these examples of increased growth of parts, previously quiescent, may depend on venous engorgement.

Plate VIII. fig. 8, is intended to show the relation of the large veins to the ovary in an old mare.

In support of this view, attention may be called to an observation by Banks (*On the Wolfian Bodies and their Remains*, 1864), that the growth of the "Organ of Rosenmüller" keeps pace with the uterus and its appendages. It has been noticed that after parturition the organ is red and tumified. In the sheep it is always best seen during pregnancy, and this condition seems to have a very decided effect upon its development.

From this it is obvious that increased blood supply does affect the parovarium, and the above facts come in as excellent testimony to the notion I have ventured to suggest, *that passive hyperæmia plays a part in causing these tubules to take on abnormal growth.*

Leaving mares, we must now pass on to consider a few examples of cysts, connected with the parovarium in other animals.

In March 1833, I communicated to the Zoological Society a paper (since published in the *Proceedings* for 1884) on the "Diseases of Carnivorous Mammals." Among the cases there recorded is an example of ovarian disease in a tiger. The animal was of splendid proportions, and had been born in confinement. It was twelve years old, death having been brought about by an attack of lobar pneumonia. Both ovaries presented abnormal conditions. The right ovary contained three solid tumours about the size of a nut, and of a reddish colour, one of them being pedunculated. Two cysts of the size of a cherry occupied the substance of the organ. The left ovary presented three of these reddish solid growths, two of firmer consistence than the rest and pedunculated. A cyst the size of a gooseberry occupied the substance of the ovary. Hanging from the meso-salpinx is a cyst the size of a cherry, attached by a narrow pedicle, whilst hanging among the fringes of the abdominal end of the Fallopian tube are numerous pedunculated cysts the size of millet seeds. The solid growths, when examined microscopically, exhibited a structure similar to corpora lutea. In this case, as in that of the mare, there can be little doubt that these cysts result from dilatation of the tubules composing the parovarium.

It seems to me that, ovarian and parovarian affections are by no means common in "wild animals," but occur with tolerable frequency in domestic animals. Many carnivorous animals have been examined *post mortem*, during the past three years, and in every case the uterus and its appendages have been particularly inspected; hence it appears remarkable that the first case should be found in tiger born and bred in the captive state! A well-marked example of cystic ovarian disease came

under my observation in a common cat. The right ovary had dwindled to the size of a split pea. The left one has two cysts developed in connection with the ovary itself, of the size of small grapes, whilst hanging pendulous from the Fallopian tube are several smaller cysts with well-marked pedicles; these smaller bodies obviously arise by dilatation of the parovarian tubules.

In an uterus and its appendages taken from a tree porcupine which lived for some time in the Zoological Gardens, the left ovary was occupied by a cyst the size of a small gooseberry, which has encroached for a considerable extent on the proper structure of the ovary, which has atrophied in consequence. There is yet a singular class of cases to be discussed:—

It is a curious and noteworthy fact that in many cases of malformed and defective uteri I have had opportunity of examining, the ovarian and parovarian bodies were the seat of cystic dilatation. The following case, taken from a goat, will serve as a characteristic example. The uterus and vagina were nothing more than a narrow tube—a papilla indicated the opening of the urethra. The uterine cornua were dilated, but they had no connection with the middle tubular portion, which were distended with thick mucus. Hanging from the ends of these dilated portions were the diminutive ovaries; the left one was absorbed in great measure by the pressure of a cyst the size of a cherry.

A critical examination of this case seems to demonstrate that the tube formed by the confluence of the two Müllerian ducts, in the usual course of development, had failed to advance any further in the formation of an uterus, and had simply persisted as a duct, merely undergoing an increase in proportions. Hence, given an imperfect uterus, the ovaries are necessarily useless structures, and become prone to assume morbid change. Such cases are by no means unknown in the human female, and the cystic ovary and parovarium represented in Plate VIII. fig. 9, was taken from a girl, aged 18 years, who possessed an uterus which had never passed beyond the “tubular” condition, or stage of confluence of the Müllerian ducts. In this case the ovary was bedecked with numerous pedunculated cysts originating in the parovarian tubules.

The facts recorded in the preceding pages ought not to be regarded as mere curiosities, in that they serve as instances of disease occurring in animals; nor should they be estimated as merely interesting in that they illustrate truths which might *a priori* have been anticipated. The investigation was originally undertaken for the purpose of determining how far the notion that *cysts may originate in functionless ducts and tubules*, would hold its ground, if the view were extended to animals in general.

How far I have succeeded must be left for others to determine. To me it has been a labour of very great pleasure, and my hope is, that others more capable of judging may not esteem this work "labour in vain," or "valueless."

EXPLANATION OF PLATE VIII.

Fig. 1. The pelvis, with the bladder, uterus, and rectum of a Macaque monkey. The uterus is anteflexed.

Fig. 2. The pelvis and its contained viscera, from a monkey. The uterus is retroflexed. The parovarium is cystic on both sides. The right ovary lay behind the fundus of the uterus, but in the drawing it is drawn out so as to show the cysts.

Fig. 3. The pelvis of a monkey (*Cercocebus collaris*). The uterus is flexed laterally, and its fundus rests on the right psoas muscle.

Fig. 4. Uterus of a Mollucca deer (*Cervus molluccensis*), showing an anteflexed fundus associated with atrophy of the anterior wall of the uterus, due to the pressure of the flexed fundus.

Fig. 5. Uterus of a kangaroo. The Fallopian tubes were distended with caseous matter—pyosalpinx.

Fig. 6. The genito-urinary organs of a male toad (*Bufo vulgaris*), showing cystic dilatation of the Müllerian ducts.

Fig. 6-a. The generative organs of the male of the common frog (*Rana temporaria*), page 130.

Fig. 7. The cloaca of a bird, with the lower end of the left oviduct. The rudimentary right oviduct has commenced to assume a cystic condition.

Fig. 8. The right ovary and Fallopian tube of a mare. The ovary has undergone atrophy, due to the pressure of cysts which occupy the meso-salpinx.

Fig. 9. The ovary, Fallopian tube, and parovarium, which is cystic, from a girl æt. 17.

Both testes were large and fully developed. On the right side the much convoluted vas deferens, 3.5 mm. in diameter, passed backwards from a full sized epididymis, and terminated posteriorly in a dilated portion (seminal vesicle) opening to the sperm sac (seminal bladder of Balfour), which was situated alongside it, and opened in its turn to the urino-genital sinus. This arrangement also is of the usual typical character found in the male skate. But whilst the testis on the left side was of the same size, and presented the same appearance as that on the right, the remainder of the male sexual organs on this side were somewhat modified in form. It was not unlikely that the testis of this side might have been imperfect, or have had a rudimentary ovary in connection with it, as occasionally occurs in frogs and toads,¹ but on examination this could not be found, and in the testis nothing but true spermatozoa in various stages of development was discovered. This testis, as seen from the ventral side, was partly, and the epididymis almost completely, hidden by the oviduct and oviducal gland. The epididymis was a little smaller than that of the right side—not in length but in bulk—and was closely connected with the oviducal gland by fibrous tissues, but otherwise was normal, presenting the usual highly convoluted appear-

¹ The presence of a rudimentary or degenerated ovary in male frogs and toads has been described and investigated by Bidder, Von Wittich, Leydig, and others; and seems to be among the latter a normal condition not only among the young, as described by Milnes Marshall (*Jour. of Anat. and Phys.*, January 1884), but also among the full-grown animals; for of 276 toads dissected in Edinburgh University Natural History Laboratory last summer, 230 were males, most of them being of full size, and having reached sexual maturity, as shown by the presence of spermatozoa in the testes. Of these 230, all had a small ovary attached to or near the anterior end of the testis of each side; the ovary in some cases being not more than 1 mm. in diameter, but in most being from 4 to 5 mm., and sometimes divided into unequal and quite separate portions. Of these males 90 per cent. had a more or less perfect Müllerian duct on each side. In some cases the duct was as much as 1.2 mm. in diameter, and complete as to its length; in others it was visible merely as a small projecting tubular thread, about .5 mm. thick and from 5 to 10 mm. long. In most cases, however, it appeared as a more or less distinct line, varying from an apparently complete duct of .25 mm. diameter to a mere fine line of thickened tissue; sometimes a short portion, 5 to 10 mm. long, varying in position, but generally near the posterior end, being of larger diameter.

Dr J. A. Smith describes (*Proc. Roy. Physical Soc. Edin.*, vol. iii., 1865) a similar occurrence of combined ovary and milt in a cod.

ance. The vas deferens was of less diameter (being almost 2 mm.) than that of the right side, but its lumen was complete, and it contained seminal fluid. It formed one or two bends near the posterior end of the epididymis, but instead of continuing its course as a convoluted duct, it ran backwards in a nearly straight line until its termination in a dilated portion or seminal vesicle, which also was slightly narrower than that of the right side.

The special peculiarity here, however, was that the sperm sac was absent, and the dilated part of the vas deferens opened directly to the cloaca, so that with comparative ease a bristle could be passed from the cloaca directly through the seminal vesicle, and thence right up the vas deferens as far almost as the posterior end of the epididymis.

It is probable that the diminished size of the left vas deferens would not have been caused merely by the abnormal presence of a persisting but incompletely developed and functionless Müllerian duct, but was due to this duct having reached the advanced stage of a true oviduct; the vas deferens not being small in size, on account of the presence of the oviduct causing an interference with the due discharge of its functions, nor from other mechanical causes, but because it suffered in its growth from the physiological effort entailed in bringing the oviduct to, and maintaining it in the fully developed condition which it here occupied.

It is likely, however, that the absence of a sperm sac was due to something more than this, viz., either that the—at this point—close proximity of the growing oviduct retarded or altogether prevented its original development, or that it atrophied on account of disuse caused by the presence of the oviduct interfering with the discharge of its functions. The vas deferens and oviduct were for the last 2 cm. of their length closely bound together by a somewhat thickened tissue, which may have been the degenerated sperm sac; but the fact of the dilated end of the vas deferens opening directly and in a simple straight line to the cloaca would seem to imply that the sperm sac had never in this case been developed.

Although it can readily be understood how the oviduct might prevent the development of the sperm sac, from its close proxi-

mity to it,¹ and how it might to a certain extent so retard the development of the Wolffian duct as to prevent its ever acquiring the large size and convoluted form of the adult vas deferens, yet it is difficult to see how it affected the arrangement of the aperture of the vas deferens. The urino-genital sinus is formed by the coalesced terminations of the two Wolffian ducts which originally open to the cloaca,² and it is remarkable that in this case the left Wolffian duct should not have followed the usual course of development, since the Müllerian duct was probably wholly split off from the original segmental duct, and became free of it before the stage of the coalescence of the Wolffian ducts to form the urino-genital sinus was reached; and as the oviduct lies ventral and external to the Wolffian duct, there was nothing to interfere with the approximation of the two ducts. Again it is noticeable that the single right Wolffian duct formed a complete urino-genital sinus for itself, with the usual median papilla through which it opened to the cloaca. Altogether the appearance presented by the condition of these organs in this skate would have led (apart from our embryological information) to the inference that the urino-genital sinus was developed separately, and was not the early conjoined terminations of the Wolffian ducts.

The right ureters opened as usual to the sinus, but the left appeared to open to the dilated portion of the vas deferens of their side.³

In the cloaca there was present, besides the anal aperture, the median urino-genital papilla; and slightly to the left of it was the small aperture of the left vas deferens; to the exterior of which again was situated the large and tumid mouth of the oviduct.

One more peculiarity remains to be noticed, as a further evidence of the perfect functional condition in which the oviduct was found.

¹ The sperm sac being developed late in the growth of the embryo, or being even a post-embryological formation (Balfour, *Development of Elasmobranch Fishes*).

² Balfour, *Development of Elasmobranch Fishes*.

³ Before this could be satisfactorily ascertained, the accidental destruction of the specimen unfortunately prevented further investigation.

This was the presence of spermatozoa in the anterior (Fallopian tube) portion. The general anatomical details described above were noted a few hours after the fish was caught, but none of the generative organs were probed nor cut into until fifty-four hours later, and probably more than sixty after the death of the animal; yet on microscopical examination of the fluid then found in the Fallopian tube, it was discovered to be full of living spermatozoa moving actively. A good deal of ciliated epithelium appeared also on the slide, the cilia moving freely; but that the motion of the spermatozoa was not due to this cause was proved by finding them moving actively in fluid which, by being more carefully removed from the duct, contained no epithelium.

I cannot think it likely that these spermatozoa got in and passed up the oviduct after the death of the fish, for no spermatozoa could be found in the cloaca and the presence of spermatozoa in the posterior part of the oviduct was doubtful, and at all events, if present, they were not motile. I conclude, therefore, that the sperms found in the upper part of the oviduct passed up there during the life of the fish, and certainly they still remained motile even after the considerable lapse of time mentioned. It is probable that these spermatozoa got into the oviduct from self impregnation, and that the oviduct and its gland were in the advanced sexual condition here found from sympathy with the rest of the generative (male) organs. Otherwise we would require to suppose not only that the physiological influence of this fully developed oviduct on the fish was such as to cause it so far to lose for a time the sense of its proper sex as to permit of its being impregnated by another male, but also to suppose the other male capable of being also misled in that direction.

EXPLANATION OF PLATE IX.

The ventral wall has been cut away to expose the reproductive organs. The alimentary tract and left testis have been removed, and both epididymes slightly displaced upwards to show the ducts.

ON THE INFLUENCES OF SOME CONDITIONS ON
THE METAMORPHOSIS OF THE BLOW-FLY
(*Musca vomitoria*). By JAMES DAVISON, L.R.C.S.I.,
L.K.Q.C.P.I., *Medical Officer, Ballinakill Dispensary, late
Demonstrator of Anatomy in the Royal College of Surgeons,
Ireland.*

DURING August and September of last year, while dissecting the bodies of some of the lower animals, I noticed that on any of those which had been exposed for a short time, the blow-fly (*Musca vomitoria*) had deposited its eggs. The favourite situations for these deposits were the mouth, anus, inside of the thighs and arms, and on that surface of the body on which the animal happened to lie. In selecting these sites, the mothers probably were influenced by the greater security they conferred on the future welfare of their offspring. I have never seen these flies depositing their eggs on perfectly fresh meat, when decomposing material was present. By its odour, they probably distinguish between dead matter which does, and living matter which does not suit their purpose. It is a curious fact that this capability, whether the result of inherited experience or conscious ratiocination, is deceived by the aroma of the plant, *Arum dracunculius*, when flowering, on which, as if it were flesh, they deposit their eggs. As usual these develop into larvæ, and, feeding on the plant until ready to assume the pupa form, when they descend and seek a place suitable for undergoing this transformation. These matters are noticed in Cuvier's *Animal Kingdom*, in the chapter on the *Diptera*. Though the writer states that this is a case of deception, the fly believing the plant to be flesh, might it not be quite conscious that it is not so, but that, possessing certain properties, it will suit its purpose. It probably has no conception of the *Arum* and flesh as such, but is conscious that both have what it desires. However, at present I will say nothing further of the psychology of these insects, than that I shall again more fully enter into the subject.

Having thus plenty of material, I was induced to try how the

metamorphosis of these eggs might be influenced by placing them under a variety of conditions. And to this I was led chiefly by reading Karl Semper's book on the *Natural Conditions of Existence as they affect Animal Life*. In this book, to me one of the most suggestive I had ever read, Semper strives to show that the problem for the believer in evolution now to solve, is how do natural conditions modify an organism so as to produce a new variety. With this interesting object in view, I undertook the performance of these few experiments, which, together with their results, I shall shortly detail. Though I did not succeed in producing a variety, nor indefinitely showing how some of the conditions employed influenced the development of the blow-fly, nevertheless I am induced to draw attention to what I have done, in hopes that (should they be considered of sufficient importance) they will encourage workers in this, a field promising such a rich harvest of results, and scarcely yet entered on by experiment.

Six experiments were performed, and the modifying conditions used were heat, light, its blue rays, and its absence—darkness. I shall now proceed to give these in detail, quoting from notes accurately taken at the time, and their sequence shall be in the order in which they were performed.

Experiment No. 1.

This experiment was made for the purpose of seeing what would be the effect of light, darkness, and the blue rays of the spectrum on the metamorphosis of these eggs into larvæ, and, further continued, it also shows the influence of these media on the change of the larvæ into pupæ. The blue rays were employed rather than any other of the colours of the spectrum, because vessels of this hue were at hand. Finally is seen the effects of some of these media on the terminal metamorphosis of the pupæ into imagines.

On Monday the 7th of August 1882, a turkey's liver, on which blow-flies had deposited their eggs on that and on the previous day, was divided into three nearly equal parts. These eggs therefore varied in age, from twenty-four hours to six, hence by so much will they differ in their times of metamorphosis. One of these pieces, and on each of which were a considerable number of

eggs, was placed in an ordinary eight ounce clear glass bottle, another was placed in a blue glass bottle of the same shape and capacity; both were then lightly corked, and the last piece was placed in a wooden box of about four inches in length and two in height; the lid was then shut down, and all wrapped up in two layers of brown paper, so as to exclude the light as completely as possible. This was done at half-past three o'clock P.M. on the day mentioned, and the three vessels were immediately placed in the window of my laboratory, which had a southern aspect. This laboratory was an out-building, and had no fire. Now, if light, its blue rays, or darkness, interfere with the metamorphosis of these eggs into larvæ, we shall here be able to see, having them placed under such circumstances as shall allow these media to exert their unbiassed powers.

At eleven o'clock A.M. on the next day, larvæ were found in each of these vessels, and in each still remained some eggs unchanged. At the same hour on the next day, all these eggs had become larvæ, nor at this time did any of these differ from each other in any of the three vessels. Of course the larvæ developed on yesterday were larger than those developed on to-day, but what I mean to convey is, that these were similar in each of the vessels. In fact, this difference of condition did not produce a corresponding difference in the metamorphosis of these eggs into larvæ. That some of the eggs metamorphosed a day earlier than others is to be accounted for by the fact of the difference in their ages, probably those laid on the sixth became larvæ on the eighth, and those on the seventh became transformed on the ninth. These eggs then occupied forty-eight hours in their hatching, if I may be allowed the term, and this process was neither quickened nor retarded by the media employed. Let us then see how the future development proceeded under the same circumstances.

At half-past four o'clock P.M. on the 11th of August I examined these larvæ, and found those in the clear glass bottle and in the wooden box were of equal size, but manifestly both larger than those contained in the blue glass vessel. I regret that I did not preserve a larva from each of these vessels, so that I might now be able by drawings, weights, and measurements to illustrate their comparative development. In my

future experiments on this subject, I shall endeavour to profit by my mistakes in these.

On the 12th, introduced into each of these vessels pieces of decomposing rabbit's liver for food; this was necessary, there being a considerable number of larvæ, and they are most voracious creatures. Those in the blue glass bottle still remain the smallest.

On the 13th the larvæ were fed on the muscles of a corn-crake, the box and clear bottle larvæ growing rapidly, the growth of those in the blue bottle not so manifest.

On the 14th, introduced more food in the shape of corn-crake's and young swallow's muscles. The larvæ comparatively remain as on yesterday, of course with some increase in size.

On the 15th, introduced more food in the form of decomposing liver of a rabbit; to them this was a luscious morsel, the softer portions of it being eaten with greater avidity, if possible, than usual. To-day the larvæ in the blue bottle are not so active in their movements as those of other vessels.

On the 16th, blue bottle larvæ still remain dull. To-day specimens from each vessel (the prevailing size being chosen) were weighed and measured. The following is the result:—

		Box Larvæ.	Clear Bottle Larvæ.	Blue Glass Larvæ
Weight,	. .	1½ grains.	1½ grains.	¾ of a grain.
Length,	. .	⅔ of an inch.	⅔ of an inch.	½ an inch.

This shows that the clear glass bottle and box larvæ were twice as heavy as those of the blue glass vessel, and also that they were longer; in length, however, the excess was not so great as in weight.

On the 17th no change to report, but on the 18th it was noticed that some of the larvæ in the blue glass vessel lie stretched out and motionless, in fact, as if dead; on being touched however, they moved.

On the 19th no change, but on the 20th two of the blue bottle larvæ had died. As these vessels now contained but some pieces of rotten flesh, and as larvæ when about to become pupæ seek for something wherein to embed themselves, for this purpose into each I put some cotton wool. Here, then, they had a nidus, when disposed towards metamorphosis.

On the 21st it was seen that during the previous night the larvæ in the box and in clear glass bottle had burrowed into, and remained in, the cotton wool. Some of those in the blue bottle did likewise, the remainder were dead.

On the 22nd one of the larvæ in the box, on the night of the 21st, had become a pupa; no change in those of the other vessels. On the 23rd all the larvæ in the box had become pupæ, and no change in those of the other vessels.

So far it is clear that the larvæ exposed to the light in the colourless glass bottle have been retarded in their metamorphosis into pupæ. If this exposure to light be the cause of retardation, some of those withdrawn from its influence should become more rapidly transformed. This I did to-day by transferring a few larvæ from the clear glass bottle into a small wooden box, the fac-simile of the one already described. Now, I said, if light be the disturbing medium, the larvæ transferred to this box, where such cannot interfere, should metamorphose more rapidly than those subjected to its influence in the clear glass bottle.

On the 24th, as a result of the previous day's change, it was seen that the transferred larvæ had burrowed in the cotton, but had not yet undergone transformation. The clear and blue bottle larvæ remain as before. To-day, in order that the clear bottle larvæ might the more fully be brought under the influence of light, I removed the cotton wool from their vessel. However, as will be seen, on the 26th, thinking that these larvæ, having nothing on which to attach themselves preparatory to their metamorphosis, and that this, irrespective of the influence of the light, might retard the process, I introduced a few hard rolls of cotton wool, to which they might cling but not burrow into.

On the 25th some of the larvæ transferred to the box had become pupæ, but no change in those allowed to remain in the clear glass bottle. To-day it was noticed that the larvæ in the blue bottle, through previously burrowed in the cotton wool, as if about to undergo their metamorphosis, were now crawling around the sides of their habitat. Some principle necessary to their performing this process must therefore be in abeyance, or their present circumstances have some baneful effects; however, no endeavour was made to determine which was the cause.

On the 26th all but four of the transferred larvæ had become transformed into pupæ, and no change in those of the clear or blue glass bottle. As before said, on this day some cotton wool was introduced into clear glass bottle.

On the 27th all the transferred larvæ had metamorphosed; no change in those in the clear and blue bottles. So far, then, this experiment doubly shows that the presence of light considerably retards the metamorphosis of blow-fly larvæ into pupæ.

On the 28th no change to report.

On the 29th some of the clear bottle larvæ had become pupæ; no change in those of the blue bottle. Larvæ then, pretty fully exposed to the influence of light, are seven days longer in becoming pupæ than those fully secluded from its effects. It will be remembered that the primary box larvæ began their transformation on the 22nd, that is seven days before those of the clear bottle.

On the 30th three larvæ in the clear bottle remain unchanged, all the others having become pupæ.

On the 2nd of September two of these three had metamorphosed; on the 5th the last of them was transformed. The blue bottle larvæ did not metamorphose, but died in that condition.

On the 17th of September the pupæ of the first box began to be transformed into imagines, that was in twenty-six days from the date of their so becoming. The pupæ of the clear glass bottle began the same transformation on the 21st of the same month. I shall now give the results of this experiment in a tabular form, premising that no further attention was paid to this final metamorphosis, and as was before said the blue bottle larvæ died in that condition.

Box eggs became larvæ on 8th and 9th August; pupæ on 22nd and 23rd August; imagines on 17th September.

Clear bottle eggs became larvæ on 8th and 9th August; pupæ on 29th August to 5th September; imagines on 21st September.

Blue bottle eggs became larvæ on 8th and 9th August; did not further metamorphose.

This shows that light, darkness, and the blue rays of the spectrum do not apparently interfere with the primary metamorphosis of these eggs into larvæ, this having occurred in each

case in the same period of time, viz., in forty-eight hours ; further, it shows that these conditions do influence the next metamorphosis of these larvæ into pupæ. That darkness is the most favourable to this process is seen by its occupying under this condition the shortest period of time, viz., fourteen days, whereas under the partial influence of light the same change requires from twenty-one to twenty-eight days to complete itself. This transformation not taking place at all under the influence of the blue rays of light, shows it to be the most unfavourable of all the conditions.

With regard to the final metamorphosis into imagines, this would show that light is favourable, for under such conditions it occurs in twenty-three days, whereas under darkness it occupies twenty-six days. Suppose that future experiments bear out the truth of these, it will then be interesting to speculate as to how these conditions act so as to produce these curious effects on the life history of blow-flies. Presuming, however, that future investigations will do so, I shall, towards the end of this paper, endeavour to give some explanation of the phenomena, believing, as I do, that truth more quickly emerges by offering a wrong theory than by offering none at all, meanwhile, I shall detail some further experiments.

Experiment No. 2.

This was instituted in order to see what would be the effect of some of the colours of light, and of comparative darkness, on the metamorphosis of pupæ, into imagines. I use the term comparative darkness, because to produce this condition an ordinary black glass wine bottle was used, and this does not completely exclude the light.

On the evening of the 17th August, some pupæ of the same age were put into three bottles of different colours, viz., green, blue, and black, these were lightly corked, and placed in the window before mentioned.

These were examined on the evening of the next day, when it was found that the pupæ of each bottle had become imagines ; those of the black bottle differed from those of the others, in that they were smaller, and more feebly pigmented, in fact, their bodies were somewhat translucent. This experiment unfortu-

nately was not carried further, in order to have seen whether or not those almost colourless imagines would become pigmented had they been allowed to remain in the black bottle.

I experimented on this subject a little further, by putting eight pupæ into an old ink jar, capable of containing about half a pint of fluid. This was lightly corked, and wrapped in two layers of black paper, and placed deeply in a vessel containing bran; here light could not enter. I examined this next evening, and found that the pupæ had become imagines, and these presented exactly the same characters as those taken from the black bottle, viz., they were small, colourless almost, and translucent. During examination they escaped, hence of their future nothing can be said.

Considered on the whole, these two experiments, I think, offer a fair presumption that light in some way or other affects the pigmentation of these flies; however, in order to speak definitely, further experiments are necessary.

Experiment No. 3.

This was undertaken in order to see the influence of temperature on the transformation of larvæ into pupæ.

On the 9th September some larvæ of two days old or thereabout, were put into a small wooden box of about three inches square, together with some food. Some more of the same larvæ were likewise placed in another box similar to the one above described, and in addition food.

One of these was placed in the window of my laboratory, the other on a shelf above my kitchen fire. The average temperature of the laboratory was 58° F. and of the kitchen 79° F.

On the 11th the larvæ in the kitchen were much larger than those in the laboratory.

On the 13th the larvæ of the two boxes were more nearly alike in size, but those in the kitchen were nearer to the pupæ condition, as shown by their intestinal canal being invisible, and the yellowish hue of their bodies. Anyone acquainted with this metamorphosis, knows that when these last two conditions are present, the pupa form is not far off.

On the 14th all the kitchen larvæ had become pupæ; no such change in those of the laboratory.

On the 15th no change in the laboratory larvæ, some of which were put into a small box and this placed on the kitchen shelf.

On the night of the 19th some of the transferred larvæ became pupæ, the remainder becoming so on the following night, that of the 20th.

On the night of the 21st those larvæ that were allowed to remain in the laboratory were transformed into pupæ.

This experiment thus doubly shows that an increase of temperature hastens the metamorphosis of larvæ into pupæ.

Experiment No. 4.

This was undertaken in order to see what would be the effect of an increase of temperature on the metamorphosis of the eggs of the blow-fly into larvæ.

On the 14th of September forty-eight eggs of the blow-fly were taken from the mouth of a dead rat, which had been exposed at the noon of this day, hence these were but a few hours old. The liver of the rat was divided into four equal parts, and on each of these was placed twelve of the eggs. One of these pieces was placed in a wide-mouthed glass vessel, with a cover of the same material, another in a small wooden match-box, and this wrapped in paper, these two vessels were then placed in the laboratory window. The other two pieces were placed in similar vessels, and these were put on the kitchen shelf before mentioned. The average temperatures of these situations were much like those detailed in the last case, viz., the laboratory 58° F., the kitchen 79° F.

At eleven o'clock on the morning of the 15th the eggs placed in the kitchen had become larvæ; no visible change appeared in those of the laboratory.

At eleven o'clock on the 16th the laboratory eggs had become larvæ.

This experiment then shows that an increase of temperature of 21° F. produces a quicker metamorphosis of these eggs into larvæ by twenty-four hours, and also that light does not affect it, the transformation taking place at the same time in the glass vessels as in the wooden ones. From this I should infer, that in hatching eggs with the hydro-incubator there is found to be

a relation between the rapidity of the process and the amount of heat employed.

Experiment No. 5.

This experiment bears on the same point as No. 4, viz., on the effects of temperature on the metamorphosis of the blow-fly's eggs into larvæ.

At six o'clock on the evening of the 22nd September the liver of a rat, which had been exposed from 11.30 A.M. on the same day, and on which was desposited blow-fly's eggs, was divided into three parts, on each of which were a number of eggs. One of them was placed in a small wooden vessel about three inches square, and this was placed in the kitchen as before. The other two were placed, one in a clear glass wide-mouthed vessel, the other in a small wooden box; both these vessels were allowed to remain in the laboratory. The temperatures of these situations were much the same as before.

On the following day, the 23rd, at 10.30 in the morning, the kitchen eggs had all become larvæ, no change in those of the laboratory.

On the 24th, at twelve o'clock noon, there was still no change in the laboratory eggs, but at four o'clock P.M. all had become larvæ. It is here worthy of remark that in all the previous experiments the metamorphosis were completed during the night, and here this has occurred during daylight.

The future of these larvæ known to me is, that on the 28th those kept in the kitchen left their dwelling in order to seek a proper place wherein to become pupæ. Here, then, an occurrence took place in five days, which in the first experiment required thirteen or fourteen days to accomplish. Seeing that the only difference in the conditions of the two experiments was the higher temperature employed in the latter, it is therefore justifiable to infer that this was the cause of the more rapid metamorphosis, both of the eggs into larvæ, and of these into pupæ. Nothing is known of the future of the laboratory larvæ.

Experiment No. 6.

This was an attempt to produce a vegetable-eating variety of these flies by placing a large number of eggs at one time, and

at another larvæ, on porridge, made from Indian meal. Now, I said, some of these might be peculiarly organised, and subsist *naturally selected* in their *struggle for existence*. However, I was disappointed, as they all died, I mean they larvæ in from eight to ten days. They kept crawling about, and did not increase in size. I thought I could detect some of the porridge in their intestinal canals; of this, however, I am not certain. During this summer I purpose repeating all these experiments, and perhaps I may have better success in producing a vegetable-feeding variety.

Observations.

Having now collected some facts in reference to the metamorphosis of blow-flies, it might be well to endeavour to form some theories to explain them, for the bringing together of a large number of facts, though in itself an excellent work, falls far on this side of tying these together by theories, at least, so says Buckle, in his *Civilisation in England*. So far, these experiments, in which light was employed as a medium, show that it does not affect the primary metamorphosis of the egg into the larva; that it does retard the metamorphosis of the larvæ into pupæ; of its influence on the further transformation into imagines I shall say nothing, the experiments not being satisfactory, though suggestive. That the larvæ dislike light is further shown by the following facts:—If a few of them be taken, and placed on the ground, so that the sun can shine on them, they will immediately endeavour to escape from it by burrowing into the earth; if unable to accomplish this, they turn tail, and hurry off in an opposite direction. I mean, in the direction opposite to which the sun then is; should this be in the south they go north, if in the west they go east. Now, if any thing be placed between them and the sun, so as to prevent its rays falling on them, or if the observer himself form a shade, they will move towards their protector. Again, if a few of them be placed in a cylindrical clear glass vessel, and this laid on a table near a lamp, they will immediately begin to crawl about, and finally locate themselves in a heap at that part of the vessel furthest removed from the light. If this vessel be then turned round, so as to bring them again nearest to the light, again they

begin to crawl, and, as before, finally settle down where least light reaches. Even in this heap many a struggle takes place for which will get undermost, and away from the influence of the persecuting light. Why then this shunning of light? As we see it in some way or other interferes with their transformation into pupæ, and this probably is the cause of their avoiding it. Is this then the cause of those phenonema in animals, which we term instinct, viz., that by acting in a certain way, under certain circumstances, they avoid something which is deleterious, and attain to something beneficial to them. Nay, might it not be, in these useful experiences of a lowly worm, multiplied and perfected, as we go upwards in the animal kingdom, in which we are to find the germs of mankind's duty, which, as Immanuel Kant says, "worketh neither by fond insinuation, flattery, nor by any threat," but for the benefit or good of himself, and of that of the entire human race.

Granted that light is harmful to these larvæ, how is it so? How does it produce its deleterious effects? Looking through the entire animal and vegetable kingdom, we see how general is the principle that the absence of light is necessary to the first stages of development of either the seed or ova. See the darkness surrounding the embryo of mammalian animals in their mothers' womb; the same is produced in oviparous animals, by the shells of their ova, and intensified by their parents sitting on them. See how fishes cover up their ova with sand and gravel, probably as well to exclude the light as to prevent them being swept away by the flood. Then, in case of vegetables, the seeds and roots are put beneath the earth before germination occurs; of course, in these, budding may take place before planting or sowing, but we know much the more vigorously when light is excluded. Of ova, those most exposed to light, so far as I know, are frogs, and in these see the provision made for its exclusion, by their being completely surrounded by a pellicle of black substance, which probably entirely prevents its entrance. This black substance persists in the process of development of these ova into tadpoles, and these too for a considerable time retain it. It might be mentioned here that those black pigment cells which are found in frogs are probably the remnants of this, and again serve to reproduce it in

their ova, and a question would be in which was it first produced; this, however, is foreign to our subject. Enough now has been said in order to show the utility of darkness in the primary stages of development, and I shall now endeavour to give a reason why such should be the case.

It is stated in Todd and Bowman's *Physiological Anatomy*, that eggs during their incubation, and plants during their germination, absorb oxygen, and give off carbonic acid gas; anything, probably, which would intensify this process would increase their rate of development. Now we know that plants in darkness absorb oxygen, and give off carbonic acid gas, and might not this also increase the same process in embryonic animals, and thereby their development. Might we say, then, that darkness proves useful in development, by increasing the rate of absorption of oxygen, and thereby the elimination of carbonic acid. I need say nothing further on this point. Experiments should first be made, showing the influence of the absence of light on the rate of oxygen absorption in embryos. Had I the necessary apparatus, I should endeavour to determine the point. The converse, however, of this might be found to be true, viz., that the rate of carbon absorption might be increased by darkness, and not that of oxygen. After all, these theories may be but nonsense; however, I think they might be worth investigating.

Are we to account for the cessation of development and death of the larvæ exposed to the blue rays of light, by saying that it interfered with their absorption of oxygen, and hence the result? Such may have been the case, but as I only made one experiment with this medium, it is hard to say whether or not the same would occur again. In further experiments on this part of the subject, I shall employ as media all the colours of the spectrum.

I shall now say a few words as to those experiments where heat was employed as a medium, and offer a theory as to how it exerts its influence. So far these showed that heat hastens the metamorphosis of the eggs into larvæ, the growth of these, and their transformation into pupæ. I did not test its influence on the final change into imagines.

The beneficial effects of heat on growth are general and well

known both in the animal and vegetable kingdoms, in proof of which I need only ask any one to compare the *feria* and fauna of the tropics with that of colder regions, and see their greater size and luxuriance. See how the grass, plants, and flowers, dormant during the cold of winter, shoot forth under the genial warmth of the first days of spring. Dr. Edwards has shown that if very young rabbits, or kittens, be removed from their mothers, they rapidly cool down to the temperature of the surrounding medium, or rather to within a few degrees of it, whereas previously they had been but little colder than their parents. We also know that, in case of animals born immature, in order to keep them alive it is necessary that they should be kept very warm. However, it is only slaying the slain, to give more evidence as to the beneficial influence of heat on development.

These eggs and larvæ underwent their metamorphoses more rapidly under a high than under a low temperature. Would we be justified in inferring from this that animals living in hot countries pass through the phases of their lives quicker, and arrive at its goal, death, sooner? I am aware of but one fact bearing on this point, and it leads me to believe that such an inference would be correct; it is this, women in warm countries arrive at an earlier maturity, and I should like to know if this is followed by an earlier decline and death.

We have now seen how useful heat is in the growth and development of plants and animals, let us then try and form some theory as to how it produces these beneficial effects. Animal heat, we know, is probably produced in three ways, the chief, of course, being the coming in contact of arterial or oxygenated blood with the other tissues, causing their oxidation, the friction of muscles, and by the ingestion of warm foods and liquids. By this we see that an animal, at least a warm-blooded one, in order to keep up its heat, consumes part of its own tissues. Suppose we keep up this heat from without, so much of the body will not then be consumed, and by so much probably will it have increased in size. This may account for the good effects of heat in the growth of warm-blooded animals, but does not do so in case of the larvæ we have been speaking of, nor in the case of any other cold-blooded animal, or in vegetables. Now,

the growth of any organism depends on two factors, or rather the relation existing between them. These factors are the amount of matter taken in and the amount eliminated, and the greater the relation the taken in material bears to the given out, the greater will be the increase in the size of the organism. Now, anything which increases the power of absorption or lessens that of elimination, will be beneficial to growth. Embryos are chiefly, at first, entirely made up of a substance called protoplasm, and this chemically consists of oxygen, nitrogen, carbon, hydrogen, with varying amounts of sulphur and phosphorus; the increase in the growth of these would depend on the amount of these gases and simple substances taken up. Elimination here does not affect the process, for such a thing to any extent does not occur in the mother's womb, nor at any time is it great in the vegetable kingdom. Therefore, I should say that heat is favourable to growing organisms, by causing them to take up a larger quantity of oxygen, carbon, hydrogen, and nitrogen. It probably does so by either rendering the compounds containing these substances more unstable, and therefore more easily absorbable, or by producing such changes in the organism as to enable it to take up a larger quantity of nutriment. Here, again, experiment will be necessary to show the powers of absorption and elimination of organisms, or rather their relative powers of so doing, when placed at a low temperature and when placed at a high one, and, as I said before, want of apparatus prevents me endeavouring to show this.

Whence arises this necessity for heat and darkness in development? Does the principle of heredity offer an answer? Mr Darwin, in his work on the *Descent of Man*, endeavours to show that those cyclical phenomena, such as the period of gestation in mammals, of incubation of eggs, and the duration of fevers, are inherited through the changes produced by the tidal waves on the Ascidian forefathers of the present animal world. In like manner, might not this necessity for heat and darkness also be inherited? Hence, probably two of the conditions of birth of Haeckel's *moneron* were heat and darkness. Finally, does not this demonstration of the utility of darkness in development lend support to the eloquent Huxley's philosophical act of faith, which he makes in his ever memorable

address on "Biogenesis and Abiogenesis." Speaking of the first appearance of life on earth, he says—"I should expect to see it appear under forms of great simplicity endowed like existing fungi, with the power of determining the formation of new protoplasm from such matters as ammonium carbonate, oxalates, and tartrates alkaline, and earthy phosphates, and water without the aid of *light*."

ON THE SOURCES AND THE EXCRETION OF CARBONIC ACID AT THE LIVER. By J. J. CHARLES, M.D., F.R.U.I., *Professor of Anatomy and Physiology, Queen's College, Cork.*

IN a paper "On the Gases of the Bile," which I published in this *Journal* in 1882, I put forward an hypothesis as to the probable mode in which albumen might, by its decomposition at the liver, produce carbonic acid. I there assumed that a molecule of albumen might be supposed to combine with 50 molecules of water, and yield 8 molecules of urea, 7 of glycogen, 5 of carbonic acid, 7 of oxygen, and 1 of sulphuric acid. The oxygen would not, of course, remain free, but might enter into combination with reduced hæmoglobin or other substances. In favour of this assumption, it should be remembered that of the 18 atoms of nitrogen in a molecule of albumen ($C_{72}H_{112}N_{18}O_{22}S$), 4 probably belong to the urea group; and also that carbonic acid has actually been obtained in the laboratory from albumen. Schützenberger had, a few years previously, advanced an hypothesis somewhat similar to mine, though I was not aware of it at the time of the publication of my paper. He assumes that 100 grammes of albumen generate first 35·5 grammes of urea, and the residue, by subsequently combining with 12·3 grammes of water, gives origin to 27·4 grammes of carbonic acid and 51·39 grammes of fat. He has further shown that albumen may be decomposed into carbonic acid, ammonia, and certain acids; and he believes that the carbonic acid and ammonia may afterwards combine in the body under the influence of electrical currents, and thus form urea. If this view prove correct, some of the carbonic acid evolved in the liver would not leave it as such, either by the blood or the bile, and would not, therefore, appear at the inner or the outer surface of the body in the gaseous form.

We can readily believe in the albumen of the tissues, particularly the muscular and the nervous, undergoing these chemical changes during its metabolism, and so account for the carbonic acid present in all the tissues, and for the urea found in some of them; but it is, moreover, probable that a part at least of the primary decomposition products of the albumen may be yielded

up by the tissues to the blood, and thus conveyed directly to the liver, where the decompositions above described may ensue. That chemical changes, such as oxidations and decompositions, occur to a large extent at the liver, is indicated by the high temperature of the blood of the hepatic vein, as well as by the great quantity of carbonic acid in the bile. In fact there can be no doubt that the destruction of albuminous material is most active at the liver, for this organ, as we know, contains about a fourth of the total blood of the body—an amount equal indeed to that in the muscular system, although this system constitutes at least half the normal body weight; besides, there is to be found in the liver a great number of nitrogenous substances intermediate between albumen and urea, such as leucin, tyrosin, xanthin, hypoxanthin, uric acid, &c. According to most authorities, also, there is more urea to be met with in this organ than in any other in the body, many physiologists even believing that the bulk of the urea formation takes place here. The urea certainly cannot be derived from the blood by a mere process of filtration into the liver; for the nervous and muscular tissues, which do not directly produce urea, contain little or none of it.

Not only, however, may albumen be decomposed at the liver and produce carbonic acid, but there are good grounds for believing that the crystalline indifferent proteid—hæmoglobin, which is a higher albumen derivative, is broken up in the liver into a number of simpler bodies—an hypothesis advanced by Dr Zuelzer of Berlin.¹ The following equation expresses the decomposition:—

$$2 \text{ hæmoglobin } (-C_{1206}H_{1970}N_{308}Fe_2S_8O_{358}) + 85H_2O + 123O - Fe_2O_3 =$$

	C	H	N	O	S
6 taurocholic acid, . . .	156	270	6	42	6
24 glycocholic acid, . . .	624	1032	24	144	...
2 bilirubin, . . .	64	72	8	12	...
135 urea, . . .	135	540	270	135	...
4 cholesterin, . . .	108	176	...	4	...
113 carbonic acid, . . .	113	...	...	226	...
	<hr/> 1200	<hr/> 2090	<hr/> 308	<hr/> 563	<hr/> 6

Or, 13·332 grammes of hæmoglobin, with the necessary water and oxygen, yield 2·486 grammes of carbonic acid. A further

¹ *Untersuchungen über die Semiologie des Harns*, Berlin, 1884.

decomposition of a smaller proportion of hæmoglobin with the formation of glycogen (taking glycogen as $C_{30}H_{50}O_{25}$; Schtscherbakoff) is also probable. Thus—



	C	H	N	O
2 bilirubin,	64	72	8	12
150 urea,	150	600	300	150
32 glycogen,	960	1600	...	800
26 carbonic acid,	26	...	...	52
	<hr/> 1200	<hr/> 2272	<hr/> 308	<hr/> 1014

Or, 13.332 grammes of hæmoglobin yield 0.572 gramme of carbonic acid and 12.96 grammes of glycogen.

Owing to the destruction of red blood-corpuscles which is constantly occurring in the spleen, &c., a considerable quantity of hæmoglobin in solution is as constantly being carried to the liver; and if this is borne in mind, it will readily be perceived that the amount thus disposed of is far from inconsiderable. To give an idea of the rate at which old red corpuscles are destroyed, and hæmoglobin at the same time set free, I may mention that a calculation has been made which indicates that the duration of the life of a red corpuscle is, at most, about thirty days.

Now, whilst it must be admitted that some of the chemical changes I have described as taking place at the liver are to a great extent hypothetical, yet there can be little doubt that, as Heidenhain and others suppose, albumen in some form is decomposed in the cells of that organ, and biliary acids and pigments formed in the same cells as the glycogen. It is true that these two processes in the liver, resulting in the formation of glycogen and bile, though both are attended by a corresponding production of carbonic acid, differ markedly in that their periods of intensity do not synchronise; and, further, in that whilst the biliary secretion continues during starvation, the formation of glycogen ceases.

The amount of carbonic acid excreted by the liver is very large. In the bile collected directly as it flowed from the liver of the dog, I found in a series of experiments I made about two years ago in Bonn, a total of 57 volumes per cent.¹ of carbonic acid, 14 per cent. of which was evolved *in vacuo*, while the remaining

¹ At a pressure of 1 metre and a temperature of 0° C.

41·7 per cent. required the previous addition of phosphoric acid to disengage it; whereas of oxygen and nitrogen there were only traces. That this proportion of carbonic acid is very great can readily be understood, when it is stated that there are only 34 vols. per cent. of the gas present in the arterial blood of the dog, and 46 vols. per cent. in the venous blood of the same animal. From the bile of the rabbit—the only herbivorous animal in which freshly secreted bile has up to the present been examined—I obtained a total of 109 vols. per cent. of carbonic acid, free and combined,—a larger proportion than has yet been discovered in the fluids of any animal—but only slight traces of oxygen and nitrogen.

With regard to the possible source of the large amount of carbonic acid excreted at the liver, two views suggest themselves :—

(a) That the carbonic acid is produced in the different tissues and organs of the body, the liver included, and some of it then passes out by simple diffusion or solution from the portal and hepatic capillaries into the bile (as may occur at the pleura in lymph exudations), the hepatic cells not being specially concerned in the process; and

(b) That in addition to this *general* formation of carbonic acid in the body, there is a *special* production of the gas at the liver, owing to the decomposition in the hepatic cells of such bodies as albumen and hæmoglobin. I have already given reasons in support of the latter hypothesis. Of the carbonic acid thus generated in the liver, part will enter the blood and a larger quantity the bile, particularly if this fluid is alkaline; just as the carbonic acid formed in the tissues passes off from them in the lymph and in the venous blood, but a greater proportion in the latter, because it exercises a stronger chemical attraction for carbonic acid. The amount of combined carbonic acid in animal fluids or secretions depends, as a rule, on their reaction. If the secretion be alkaline, more of the tissue carbonic acid will leave the body by that fluid than by one less alkaline, while if neutral, or particularly if acid, scarcely any combined carbonic acid will be found in it as compared with the total carbonic acid in the blood. A good example of this can be observed in the case of bile. If the bile of a dog is alkaline,

as it is usually, 100 vols. may contain 57 vols. of carbonic acid; while if acid, there may be in 100 vols. only 5 vols. of the same gas. Urine, again, which is acid, contains only 14 vols. per cent. of carbonic acid; while in alkaline saliva there may be present as much as 50 per cent. But in herbivorous animals, in which the bile is more alkaline than in carnivorous, there is a proportionally larger amount of carbonic acid, and this greater richness in the gas may be the case as well with the other fluids of these animals, though this has not yet been determined.

Accordingly, from the proportion of carbonic acid in the bile, it would be unsafe to estimate the total amount of carbonic acid generated in the liver; for if the bile formed be less alkaline than the blood flowing away from the liver, the greater part of the carbonic acid will probably be conveyed away by its means to be excreted elsewhere. I am not aware that any experiments have been made as to the relative quantities of the carbonic acid in the blood of the portal and hepatic veins—an exact knowledge of which would be most useful in our present inquiry, and without it I do not feel myself in a position to say more on this subject.

**A METHOD OF MACERATION; BEING A DESCRIPTION OF
THE METHOD IN USE AT THE OWENS COLLEGE, MAN-
CHESTER. By A. M. PATERSON, M.B., C.M., M.R.C.S., *De-
monstrator of Anatomy at The Owens College.* (PLATE X.)**

I. Description of the Room (fig. 1, A).—The Owens College macerating room is a chamber about 33×15 feet in area and 11 feet in height. There are four large windows along one side; on the other side are three windows and the door. The floor is of concrete, sloping to the side of the room opposite the door; and along this side is a gutter, which runs from the ends downwards to the centre. In the centre of the gutter is a grid connected by a pipe with the drain. The grid is so constructed as not to allow of the passage of anything larger than one inch.

The present building has been in constant use for the last two years. It is separated entirely from the Medical School; while it is in close proximity with the furnace which supplies heat to the College buildings B.

II. Connections to the Furnace.—The relations of the macerating room to the furnace building are important:—*firstly*, the latter supplies the steam by which the macerating room is heated. The tall chimney C passing up from the furnace close to one end of the room, is connected, *secondly*, with the ventilating apparatus, by means of a pipe which carries the out-going air into the chimney D; and *thirdly*, with the cremating chamber, a pipe E between the chamber and the chimney acting as a chimney for the former,—so that the furnace (1) supplies heat to the macerating room directly, and indirectly (2) removes the foul air, and (3) the products of cremation.

III. Water Supply.—There is a large tap at one side of the room, connected by a 1-inch pipe directly to the main; thus obtaining the full force of water. To this tap a large hose is attached, capable of reaching to any part of the room. A reserve cistern is also provided, holding about a cubic yard of water, and used to supplement a short service, as it is inconvenient, in time of drought, to find the water from the main cut

off. By means of the hose the tanks and the sink for washing bones are filled; and the flushing of the tanks and other requirements of the macerating room are simply and conveniently provided for, without the expense and complication that a system of pipes and taps for the supply of cold water would cause. There is no hot water laid down.

IV. *Heating Apparatus* (fig. 1, F).—The heating of the room is effected by means of steam pipes. Two 3-inch pipes pass round the room beneath the windows. These are connected by another pipe with the boiler, which provides the heat for the College, and lies in the furnace room adjacent. The amount of heat is regulated by a wheel which opens or closes a valve in the entrance pipe. Thus the desired quantity can always be got; a temperature of 60°–70° is maintained in both summer and winter.

Hot water can be obtained in the sink (fig. 2) at any time by means of an arrangement connected with the heating apparatus. (It is often necessary to wash bones, and hot water is preferable to cold for that purpose.) The sink stands beneath the upper of the steam pipes which pass round the room. Into the sink hangs a T-shaped tube, branching off from the main pipe, and closed by a stop-cock placed in the vertical portion. The cross-bar of the T is perforated with holes. When required for use the stop-cock is turned, allowing the steam to work through the perforations into the cold water in the sink, and thus providing any temperature of water whenever necessary.

V. *Ventilation*.—The ventilation of the macerating room is as nearly perfect as it is possible to have it in a building of this kind. There is no smell. At one end of the room, near the floor, is a large grid (fig. 1, G), closed by a metal flap; at the other end, near the roof, are three smaller ones H, shut off in the same way. From the latter a large pipe conducts air from the macerating room into the furnace chimney. When the flaps of the grids are opened, the air enters by the large grid near the floor, creates a strong draught throughout the room, and, passing out through the small grids, is conducted by the pipe into the chimney. The connection with the chimney, by means of the hot air which passes up it from the furnace, causes the foul

air from the macerating room to be sucked out through the pipe.

Besides this contrivance, which works admirably, the cremating chamber, when in use, assists in ventilating the room by exhausting the air. In summer time, also, the windows are utilised.

VI. *Tanks*.—The tanks have been a source of considerable difficulty. At Owens College tanks of slate, lead, zinc, and earthenware have been tried at different times.

(a) Slate tanks were in use before the new building was erected. The great objection to them was that they blackened the bones in the process of maceration.

(b) A large tank of lead in the present room has the same fault. The fluid becomes inky, and stains the bones and the tank-walls, besides any painted wood, &c., with which it comes in contact. This black material (sulphide of lead) permeates the bones, and adheres so closely to the tank-walls, &c., as to render the cleansing of the tanks and the proper maceration of bones impossible.

(c) Recently a zinc tank has been introduced, modelled after the design of the macerating tanks in use at Graz. The whole tank is of zinc. The lid is provided with a rim of the same metal, which, when the lid is down, fits into a narrow gutter running round the top of the tank. When the tank is in use this gutter is filled with water, consequently, the lid being down, no disagreeable smell escapes from within. The tank is emptied by a large tap placed near the bottom. As in the case of other metal tanks the zinc takes in a crust of sulphide, but, this being white, does not discolour the bones, and does not seem to interfere with successful maceration. The great objection to the zinc tanks is their expense. The one described, with a cubic area of about $2\frac{1}{2}$ feet, cost £5.

(d) Large enamelled earthenware jars have been found to make the best medium for maceration. Large "crops" are generally used at Owens College, and have many advantages over other materials. They are eminently clean—being coated with enamel inside, and, for the most part, outside as well. This prevents any soaking of fluid into the earthenware. They are scoured most easily, and serve all the ordinary purposes of

macerating tanks more efficiently than any other material. The one objection to them is, that in the case of the largest animals, they are too small. In such emergencies the larger metal or slate tanks have to be employed. This is only a secondary defect, as the largest animals do not appear too often.

In connection with these earthenware tanks may be mentioned the troughs now being made for feeding cattle (out of a strong, coarse, white pot). These are larger than the "crops" usually made, and would probably serve the purpose even better. They have not yet been tried at the Owens College.

It is necessary to say that lead is sometimes used in the glazing of the earthenware tanks. Such enamelled jars should be avoided. The sulphuretted hydrogen evolved in maceration combined with the lead, and produces the same effects, by means of the sulphide, as in the case of the leaden tanks, making such "crops" unfit for use, as the bones become blackened.

VII. *Flushing of the Tanks*.—This is effected by means of the india-rubber hose mentioned above. The pot tanks have this advantage, that they especially admit of flushing in a very simple and effectual manner. A stream of water is directed by the hose into a "crock," the top of which is covered by a sieve of perforated zinc. The fluid from the overflowing "crock" then passes through the sieve, and over the sloping floor to the gutter, by which it is directed to the drain. Having set this arrangement in working order, Mr Hardy, the curator, is able to leave the room while the water in the "crock" is being changed, allowing for ventilation and the necessary time for the water to be thoroughly renewed. He comes back to find the "crock" filled with pure water, while, on account of the presence of the sieve, the smallest of the bones are retained. The unwholesome smell caused by the agitation of the macerating material is by this means avoided, as well as the emptying of tanks by taps, and necessary renewal of water. At the same time the flushing of the tanks is effectively performed. The bad smell in the process of cleaning the tanks was found to be very objectionable.

VIII. *Cremating Chamber* (fig. 1, K).—This is an oven built in the wall of the macerating room, and communicating, as before stated, with the chimney of the furnace. The dimensions of the chamber are about $3 \times 1\frac{1}{2}$ feet and 2 feet high. The

process of cremation is simple and expeditious; the flesh, being stripped from the bones as far as possible, is placed in the oven in layers, each layer of flesh alternating with one of red hot coals. The connection of the chimney of the chamber (E) with that of the furnace creates a strong draught, allowing the flesh of the largest animal to be completely destroyed in one hour. The benefit of this arrangement is obvious. All the carcase is disposed of on the premises. There is no carting away of stinking flesh; everything is done on the spot, and that cleanly and effectually, without the offensiveness that any other mode of removal would cause. The idea of a cremating chamber was borrowed from Professor Huxley's establishment at South Kensington.

IX. *Process of Maceration.*—Under these conditions the whole process of maceration is highly satisfactory. It is both rapid and complete. An animal is brought in and flayed. The flesh is then subjected to cremation; and the skeleton, being cleaned as far as possible, is placed in one of the macerating tanks. If the animal is large, the limbs, &c., are separated from other parts, and the skeleton reduced to a convenient size for immersion. The tank is flushed from time to time in the manner described, and after a certain interval an excellent skeleton is obtained. In summer time the process is sometimes inconveniently rapid, causing skeletons to accumulate in Mr Hardy's hands. Carnivores, it is found, require a time for maceration four times as long as that necessary for vegetable feeders, in order to procure a good skeleton. For instance, a jaguar recently required four months, while a zebra took exactly a month.

Before concluding this account of maceration as performed at the Owens College, it is necessary to refer to accounts which have been published of two other methods of maceration.

(a) In the *Journal of Anatomy and Physiology*¹ Professor Struthers has described the mode adopted by him in Aberdeen. His method presents several marked differences from the one described above.

Firstly.—Large wooden tanks are used.

Secondly.—The heating apparatus consists of an arrangement

¹ Vol. xviii., 1883, p. 49.

of pipes, containing hot water, and passing *into the interior* of the tanks.

Thirdly.—The flushing of the tanks is provided for by a system of pipes and taps.

(b) In His and Braune's *Archiv* for 1877,¹ Professor Planer describes the elaborate arrangements for maceration used at the Anatomical Institute at Graz. The tanks are of zinc, similar in essential points to the one described above, but more elaborate on account of the accessory fittings for the carrying off of foul gasses, and for the supply and renewal of water. The heating apparatus is most complicated. A pipe brings a supply of cold water; this pipe bifurcates, one stream passing to a boiler to be heated, the other to the tanks. The boiler is heated by gas, the hot water passes from it by a pipe which gives off a branch to each tank. This branch is joined by a similar one from the *cold water pipe*, so that the hot and cold water are mixed together before reaching the tanks. The mixed stream then enters the tank near the bottom; near the top of the tank is a complicated valve, which allows the superfluous water to flow away. There is also a tap near the bottom, for the purpose of emptying the tank when necessary. This arrangement for blending the hot with the cold water is for the purpose of keeping an equal temperature in the supply of warm water in the tanks. But this is not all. Passing from the lid of each tank is a tube, communicating by one end with the air inside the tank, at the other end with a larger tube, which passes through the room in a slanting direction; it opens into the outer air near the floor at one end, near the roof at the other. At the upper end, its mouth opens into a chamber in which a gas flame burns. This, by exhausting the air in the large tube, is supposed to withdraw the foul gases from the tanks, and to provide for their ventilation. These elaborate arrangements may be successful in operation, but simpler systems are found to be quite as effective; and, moreover, it is obvious that the enormous cost of fitting up such a macerating room with gas, boiler, hot and cold water pipes, and a sufficient number of zinc tanks, would be enough to make the system impracticable.

¹ Planer, "Aus der Anatomischen Anstalt in Graz," *Archiv für Anatomie und Physiologie*. Anatomische Abtheilung, Leipzig, 1877, p. 273.

The method of heating by means of steam ; the use of enamelled earthenware tanks, and the simple and convenient means by which they may be flushed ; the admirable system of ventilation ; and the process employed for the disposal of the soft parts *in situ* by means of cremation ; are the chief points in which the macerating room at the Owens College claims to excel, and on which its efficiency depends ; an efficiency, which, I should state in conclusion, is entirely due to the exertions of Professor Morrison Watson. It was he who devised the scheme, and it was under his directions that it was elaborated.

EXPLANATION OF PLATE X.

Fig. 1.—Semi-diagrammatic sectional view of macerating room and boiler house. A, Macerating room ; B, boiler ; C, shaft from furnace ; K, cremating chamber ; E, chimney of same entering shaft ; G, grid for admission of air ; H, grid for exit of air ; D, pipe conducting outgoing air into shaft ; F, steam pipe passing from boiler and dividing into two, which pass all round room.

Fig. 2.—Showing arrangement for heating water by steam in the sink A. The steam pipes are B and C, and the T-shaped pipe is shown projecting down into the sink.

FLOATING KIDNEY. BY DAVID HEPBURN, M.B., M.R.C.S.
Eng., Demonstrator of Anatomy, University of Edinburgh.

THE following appearances were observed on opening the abdominal cavity of a female subject in the practical anatomy room of the University:—

The liver extended 1 inch beyond the free border of the ribs at the level of the ninth costal cartilage. Projecting from under cover of the liver, a large body of a flattened ovoid shape was seen, and it reached to within $3\frac{1}{2}$ inches of the right pubic spine. Transversely, it passed to within half an inch of the mesial plane. Its long axis was directed downwards and inwards from right to left, and measured 5 inches. Its greatest breadth was 3 inches.

On further examination this body was found to be the right kidney occupying a very abnormal position.

I directed the attention of Professor Turner to the abnormality, and at his request I made a careful examination of the position and relations of this displaced organ.

(a) *Position.*

The kidney rested upon the posterior abdominal wall, and occupied portions of the umbilical and right lumbar regions. Its lower extremity overlapped the right common iliac artery and vein. Although not possessing a meso-nephron, its attachments nevertheless admitted of a considerable range of movement in all directions. Thus, on being grasped by the hand, it could be freely raised from the posterior abdominal wall for a short distance; whilst, both laterally and vertically, it could be displaced for several inches. It could not be forced to occupy what would have been its normal position.

(b) *Relations.*

1. *To Intestine.*—The stomach occupied the left hypochondriac region, and the pylorus lay at a point $1\frac{1}{2}$ inches internal to the lower border of the eighth right costal cartilage.

From the pylorus the duodenum passed to the right for a distance of 2 inches, when it came in contact with the left side of the gall bladder and the upper or left border of the kidney.

It immediately turned downwards and to the left, and crossed the mesial plane obliquely, appearing in the left iliac fossa close to the sacral promontory. In this part of its course it passed underneath the transverse colon, the root of the transverse mesocolon, and the superior mesenteric vessels, keeping close to the left or lower extremity of the kidney. From the left iliac fossa the duodenum turned abruptly upwards for a distance of two inches in the vertical direction.

Here it again made a sudden turn, this time to the right, and then it became continuous with the jejunum.

The course of the duodenum from the pylorus to its junction with the jejunum might therefore be said to somewhat resemble the figure six (6). Besides this, the last part, namely, that which turned upwards from the iliac fossa, was supported by a triangular slip of tissue—"the muscle of Treitz"—fully 2 inches in length, having its apex directed upwards, and its surfaces right and left. The base was 1 inch in breadth and was attached to the bowel.

This last-mentioned part of the duodenum is worthy of special notice, for it seems to be an exaggerated form of a condition which is normally present, though only to a slight extent. Thus, normally, as may be seen from Dr Bruce Young's description,¹ there is always a slight upward turn at the point where the duodenum turns *forwards* to join the jejunum, and there it is supported by a band of fibrous material descending from the left crus of the diaphragm and the tissue around the celiac axis. According to Treitz, plain muscular fibres come from both these sources to the duodenum.²

Another interesting feature in the case under consideration is the direction of the commencement of the jejunum which was to the right instead of to the left, as in normal cases.

Nothing further worthy of note was observed in the small intestine. The ileum joined the cæcum in the right iliac fossa as usual.

The colon, instead of ascending from the cæcum to the under surface of the liver, and there making its hepatic flexure, passed at once towards the left hypochondrium, crossing over and being

¹ An Abnormal Disposition of the Colon, this *Journal*, Oct. 1884.

² *Vide Quain's Anatomy*, 9th ed., vol. ii. p. 610.

attached to the anterior aspect of the kidney, by peritoneum, forming a short mesocolon, which was continuous with the meso-cæcum. The ascending and transverse portions of the colon had the same direction, *i.e.*, oblique. They formed a loose coil along the lower border of the stomach. At the inferior extremity of the spleen, the colon made its splenic flexure, and thereafter descended to the left iliac fossa.

The sigmoid flexure had a shorter mesentery than usual.

The gall bladder was almost empty, and projected from underneath the liver, occupying the angle formed by the commencement of the duodenum and the kidney, and overlapping the latter. The right lobe of the liver also overlapped the kidney for about 2 inches.

2. *To Peritoneum.*—In a normal condition, the peritoneum investing the cæcum and ascending colon may be looked upon as leaving these viscera on their lateral aspects; but in this case, owing to the altered position and direction of these organs, the peritoneum may be said to leave their upper and lower surfaces. Now, on following the peritoneum upwards and downwards, from that part of the mesocolon lying upon the anterior surface of the kidney, it was found to be distributed in this manner:—

Upwards, it passed from the mesocolon over the anterior surface of the kidney to its upper border, from whence it was continued on the posterior abdominal wall to the under surface of the liver on which it was reflected, to assist in forming its right coronary and right lateral ligaments. The same layer, when traced to the right, at the level of the kidney, became continuous with the peritoneal lining of the anterior abdominal wall; when traced to the left, at its upper part, it became continuous with the posterior lining of the foramen of Winslow; while at its lower part it passed over the commencement of the duodenum to the anterior surface of the stomach.

Downwards, it passed from the mesocolon over the anterior surface of the lower half of the kidney, and became continuous with the peritoneal investment of the cæcum and iliac fossa; while, when traced to the left, it was continued over the anterior aspect of the superior mesenteric vessels.

The ileo-colic artery, invested by a fold of peritoneum, curved outwards in close relation to the lower border of the kidney.

The peritoneum could be readily stripped off the surface of the kidney, which showed numerous cysts, varying in size from a small marble downwards. These did not form projections on the surface of the kidney, and were quite flaccid.

A small quantity of fat and areolar tissue intervened between the under surface of the kidney and the psoas muscle.

The hilus was directed upwards and inwards towards the mesial plane.

The relative position of the structures entering the hilus was, vein, artery, ureter, from before backwards, although one small branch of the renal artery passed into the hilus behind the ureter.

The right renal vein measured 2 inches in length, and joined the inferior vena cava at a very acute angle.

The right spermatic vein joined the inferior vena cava on its anterior aspect.

The right renal artery descended to the kidney in a very oblique manner. It measured 3 inches in length, and occupied its proper position between the vein and ureter.

The ureter emerged from the posterior aspect of the hilus, and passed downwards towards the pelvis, under cover of the lower part of the kidney, and lying posterior to the renal artery. From its point of emergence from the hilus until it crossed the external iliac artery, the ureter was slightly dilated and tortuous, and measured 5 inches, while the actual distance between these two points was only 3 inches.

The case just described is another instance of that interesting condition which is variously designated by the terms displaced, movable, or floating kidney,—terms indicating different degrees of the same abnormality. It was first described by M. Rayer¹ in 1841, and since then it has attracted a considerable share of attention.

Some observers have doubted the existence of this condition, and not unnaturally, for, if its occurrence were so common as some physicians would lead us to believe, from the frequency with which they diagnose it, then displaced or floating kidneys ought to be no rarity in the dissecting-room. However, such is not the case. On the contrary, Professor Turner, whose experience in teaching anatomy extends over a period of thirty years,

¹ Rayer, *Traité des Maladies des Reins*, t. iii., pp. 783–801.

informs me that the specimen which constitutes the subject of the present notice is the only one he has ever seen.

Indeed, only so recently as last summer, in the course of a lecture to his demonstration class, he took occasion to remark that he doubted if this condition were so common as some supposed, considering the rarity of autopsies.

On the other hand, in cases where a diagnosis made during life has been followed by a *post-mortem* examination, the accuracy of the diagnosis has not always been verified. Indeed, in one remarkable instance, which for seven years had been regarded as a floating kidney, the *post-mortem* revealed a fibrous tumour of the uterus.

When such errors have occurred even at the hands of distinguished physicians, and in view of the possibility of their recurrence, only those cases which have been corroborated by subsequent autopsies should be accepted as authentic instances of floating kidney.

If the recorded instances of this abnormality are thus divided into two groups,—one in which autopsy followed the diagnosis, and another in which it was not so substantiated,—we find that the former group is very small as compared with the latter. In an elaborate article on floating kidney by M. Fritz,¹ there is given a *résumé* of no less than thirty-five cases, but he only quotes one or two autopsies, and remarks “that the autopsies I have been able to study have not supplied me material of a useful kind.” Nevertheless, the existence of this abnormality has been placed beyond dispute by former reports of cases which have appeared from time to time, and specially by the report of a committee appointed by the Pathological Society of London in 1876 to investigate this subject.² In many cases the condition has been recognised for the first time on the dissecting-table, and very often there has been no previous history pointing to the probability of a floating kidney. In the present instance, from the circumstances of its discovery, it was not possible to obtain any history. When we compare it with those already recorded some noteworthy peculiarities are manifest.

The most striking difference is the coincident displacement of

¹ *Archives Général. de Med.*, 1859, pp. 158 and 301.

² *Trans. Path. Soc. Lond.*, 1876.

the intestine, namely, the blending together of the ascending and transverse portions of the colon, and the oblique position they occupy, together with the arrangement of the duodenum.

Such a coincidence is not new, however, for M. Rayer¹ remarks that displacement of the kidneys sometimes accompanies displacements of the intestines or uterus, but this has been noted in very few cases. Dr Moxon² records a case in which it is stated that "the colon allowed it (the kidney) to come into view by forming a renal flexure rather than an hepatic."

Mr Durham³ mentions an instance in which "the descending colon formed no sigmoid flexure in the left iliac fossa, but passed across the last lumbar vertebra and entered the pelvis on the right side of the sacrum." In this case the left kidney was movable.

In none of the records which I have read was there any mention of displacement of the duodenum, and, with the exception of the cases above quoted, the position of the intestines does not seem to have called for special notice.

I would next direct attention to the disposition of the peritoneum over the surface of the kidney. Girard⁴ had a case in which the right kidney possessed a mesentery nearly two inches long. The kidney floated at the level of the third lumbar vertebra internal to the ascending colon. A meso-nephron, however, is rarely found, and it seems to result from a turning over of the kidney, whereby the convexity comes to point towards the vertebral column, and the posterior surface lies in front. Most frequently the displaced kidney is merely situated more or less loosely in the cellular tissue under the peritoneum, whereby a greater or less degree of mobility results. In my case, as already described, the mesocolon was found crossing the anterior surface of the kidney, and the peritoneum so loosely disposed as to permit of a wide range of movement.

The side on which this displacement was found is also interesting. In most cases it is the right kidney which is out of place, as in the present one. In ten autopsies,⁵ eight showed

¹ Rayer, quoted by Fritz., *ib.*, p. 167.

² *Trans. Path. Soc. Lond.*, vol. xxvii., 1876, p. 471.

³ *Trans. Path. Soc. Lond.*, vol. xi., 1860, p. 142.

⁴ Girard, quoted by Fritz., *ib.*, p. 163.

⁵ *Trans. Path. Soc. Lond.*, vols. xi. and xxvii.

the right kidney to be affected, and two the left. M. Fritz gives the same proportion, viz., 4 to 1. M. Rayer also remarks that it is much more frequent on the right side than on the left. It has been said that when both kidneys present this condition the right one is the more mobile.

As regards the sex, M. Fritz, M. Rayer, and Dr Hare¹ found by far the greater number in females, and in the ten cases mentioned above, eight were in females. It will be remembered that the present case is also that of a female.

The age at which it occurs is variously stated. Fritz had met with no case below the age of 18 years, and he gave from 25 years to 45 years as the limits of its most frequent occurrence.

Dr Legg² records a displacement of the right kidney in a boy aged 3 years.

The object of the present paper has been to record a case of floating kidney, and to summarise a few of the leading facts in connection with this abnormality. It is, therefore, not necessary for me to discuss the theories of its causation, and, besides, these have been taken up in detail by M. Fritz in his paper so often referred to. Suffice it to say, that observers are inclined to regard it as an acquired rather than a congenital condition. Still, the latter mode of origin cannot be lightly overlooked, and when we find coincident displacement of the intestines to such an extent as in the cases quoted, and notably in the present one, we cannot avoid the conclusion, that sometimes, at least, its origin is congenital. This opinion is strengthened by the study of the condition of the intestinal canal at an early stage of its development, when it consists of a simple tube, showing a slight dilatation, which corresponds to the stomach. Below this there is a loop of intestine projecting forwards in the region of the umbilicus. From this primary loop, the duodenum, the ascending colon, and the right half of the transverse colon are developed. Now, these are exactly the parts of the intestine which are displaced in the present specimen, and there were no traces of inflammatory adhesions, as was the case in the "Abnor-

¹ *Med. Times and Gazette*, 1860, vol. i. p. 30.

² *Brit. Med. Jour.*, January 8, 1876.

mal Disposition of the Colon," referred to above.¹ Moreover, in the human fœtus, the kidney has acquired its peculiar bean-like form at the tenth week ; and it is about this time that the primitive colon is crossing over to its permanent attached position on the right side of the mesial plane. Consequently, a kidney situated further down than usual, as was the case in my specimen, would act as an obstacle in the way of the colon, and a condition of parts analogous to those under consideration might easily result. Again, bearing in mind that the kidney and outer wall of the intestinal tube are both developed in mesoblast, and that the peritoneum is formed by local "superficial delamination from the mesoblast,"² it does not seem inexplicable that displacements of the kidney and intestines should be associated together.

There are some prominent predisposing causes, *e.g.*, increase in the volume and weight of the kidney, as in hydronephrosis. M. Urag³ gives an autopsy of such a case.

Tight-lacing is strongly blamed by M. Cruveilhier,⁴ and the reason assigned for the greater immunity of the left kidney, as compared with the right, is the fact that it is better supported and protected from injurious pressure by the fundus of the stomach.

Finally, some interesting complications have been noted. Thus, by lying in front of the aorta the displaced organ may transmit its pulsations and so simulate aneurism. Death has resulted from obstruction of the bile duct by a displaced kidney.⁵ Horse-shoe kidney⁶ has also been found as the result of a floating kidney uniting with the opposite one.

¹ *Vide this Journal*, October 1884.

² *Quain's Anat.*, 9th ed., vol. ii. p. 882.

³ Urag, quoted by Fritz.

⁴ Cruveilhier, quoted by Fritz.

⁵ *Gazette des Hôpitaux*, October 2, 1876.

⁶ *Brit. Med. Jour.*, January 8, 1876.

THE MOVEMENTS OF THE ULNA IN ROTATION OF
THE FORE-ARM. By THOMAS DWIGHT, M.D., *Parkman*
Professor of Anatomy at Harvard University, U.S.A.

It has been almost universally taught until recently that in rotation the radius revolves and the ulna remains at rest. This view was attacked some years ago by Lecomte,¹ who held that both bones rotate, and, indeed, that usually the ulna describes a larger curve than the radius. These papers attracted more ridicule than serious attention, but now the whole subject has been reopened by Professor Heiberg,² of Christiania, who defends the theory of the rotation of the ulna. He supports his views by experiments on the cadaver, which Lecomte thought misleading, and gives an admirable synopsis of the whole history of this interesting question. The book need not be reviewed here, as it has been done by Mr Wagstaffe in the *London Medical Record* for July 1884, and, indeed, I am indebted to this notice for my first knowledge of it. Mr Wagstaffe appears to accept the new doctrine, as he "hopes to see the results of Professor Heiberg's observations incorporated in our anatomical and surgical text-books." So also does Professor Kollmann, who notices the book in *Virchow und Hirsch's Jahresbericht*. It is, therefore, rather surprising that the question should have raised no discussion.

It cannot be denied that the appearance of a rotation of the ulna is very striking, and also that Professor Heiberg states his case very forcibly. He points out that we can pronate the hand by keeping the ulna fixed and turning the radius around it in the classical way, but that we can make the axis of rotation lie in any finger we please, and that this becomes more evident if we hold a gimlet or a corkscrew between different fingers in turn. He claims that we must so modify the theory of the rotation of the fore-arm on an axis running through the head of the radius and that of the ulna, as to teach that this axis is itself in motion

¹ *Archives générales de médecine*, Août, 1874, et Mai, Juin 1877.

² *Ueber die Drehungen der Hand*, Wien und Leipzig, Urban und Schwarzenberg, 1884.

owing to a rotation of the ulna. He believes that a point in the greater sigmoid cavity is the centre of rotation, the lower portion of the bone describing the surface of a larger cone, and the olecranon that of a smaller one. "Thus the rotation of the fore-arm is due to the combined and complementary movements of the two bones, both of which rotate. It is true that the excursion of the radius is usually the greater, but the ulna can rotate alone."¹

Heiberg's most striking experiments consist in fixing small rods fitted to draw lines into the lower ends of the radius and ulna, so as to lengthen them (the hand having been disarticulated), and to show that on rotating the fore-arm, each rod traces a curve.

The purpose of the present paper is to show that, while Professor Heiberg's observations are correct, his interpretation is wrong; that though the ulna may move in rotation it does not rotate.

I have for several years shown the following experiment in my lectures:—Grasping the left wrist with the thumb and a finger of the right hand, I point out that not only has the lower end of the ulna during pronation gradually passed from the inner to the outer side of the wrist, but that it could be felt moving against the enclosing finger. I then show that a precisely similar movement appears to occur in the undissected arm of a cadaver. The next step is to show that this appearance is in part at least deceptive, or, more accurately, that the deduction from it that the ulna rotates is entirely false. A cut down to the bone is made on each side of the wrist, and large headed pins, five or six inches long, are fixed into the outer aspect of the radius and the inner of the ulna. The soft parts must be sufficiently divided not to press on the pins when the arm is twisted. The pins are at right angles to the long axis of the fore-arm, and when the hand is supine are both horizontal. On pronating the hand, the radial pin is seen describing a large curve, while the ulnar pin remains at rest. The force may be applied by twisting any finger without altering the result. I have sometimes thought that, after the movement had reached its normal limit, some very slight

¹ "Die Drehungen des Vorderarms werden somit gegenseitig vicariirende Functionen der beiden Knochen, welche beide rotiren; der Ausschlag des Radius ist zwar in der Regel der grössere; es Kann aber auch die Ulna allein rotiren."

rotation of the ulnar pin could be produced by violent pronation, but only when the force used was so great as to make the conditions quite unnatural.

After reading Professor Heiberg's book with great interest, I performed this experiment on a partially dissected arm, with the usual result. Having then disarticulated the hand, and the humerus being held in a vice, I grasped the lower ends of both bones at once with a very strong pair of toothed forceps and endeavoured to twist them, which, of course, should be possible, according to Heiberg's theory, but the bones began to break without any movement occurring in the pin in the ulna. I once more performed the experiment with the pins on a fresh subject, a young male. After that I removed the hand, and fixed short rods bearing brushes into the lower ends of the radius and ulna according to Heiberg. On pronating the hand, I saw to my astonishment each brush describe a curve on the paper held against them. That in the radius travelled upward, inward, and downward; that in the ulna made a much smaller circuit downward, outward, and upward. The movement of the ulna was not forced nor unnatural. The rods appeared to begin to move at the same instant. Once or twice I thought that the ulna began the least fraction of a second before the radius.

Much perplexed, I repeated the observation again and again, till my eye fell on the pin that had been fixed in the ulna at right angles to its shaft for the previous experiment, and I saw that though the brush in the end of the ulna was describing curves, the pin was doing nothing of the kind. It is perfectly evident that if the ulna were really rotating, this movement would be shown by the head of the long pin. For further proof I laid bare the inner surface of the shaft of the ulna for some distance above the head, and painted a line on it running up the arm. This showed no tendency to pass out of sight during rotation, except perhaps very slightly, when excessive force was applied.

It was clear, therefore, that Heiberg's ulnar curve must be accounted for otherwise than by rotation of the ulna. Watching more closely than I had done the head of the long transversely placed pin, I tried to analyse some slight movements which I had regarded as merely accidental. The most definite of these was a tendency to abduction at the beginning of pronation.

These movements varied with the application of the force, and I was soon convinced that the curve which Heiberg mistook for a sign of rotation of the ulna is simply the effect of combined lateral and vertical movement. If two constant forces are applied at right angles to each other, the object acted on will move in the diagonal, but if the forces are of varying intensity, more or less complicated curves will result.

These experiments decide a disputed point, namely, that lateral movement occurs in the elbow-joint. It can be readily shown by fixing the humerus in a strong vice, after the removal of the soft parts, and marking the extent of the movements by a short pin driven through the styloid process of the ulna, so as to project at the back of the wrist. When the arm is fully extended, it may be doubted if there is any lateral movement, but as soon as it is even slightly flexed there is no doubt at all. When the fore-arm is carried up to right angles with the arm, it is found that the movement is no longer as free as it has been. It is a curious fact that this lateral movement is more extensive when the fore-arm is prone, and this may have some bearing on the curves drawn in Heiberg's experiment.

In case it should be objected that, as I obtained these movements on a cadaver, it does not follow that they occur during life from muscular action, I would call attention to an experiment by Heiberg which removes the doubt. A long rod was firmly fastened along the ulna of a living person, and allowed to project for some inches behind the elbow. The person then executed the movements of boring, and curves were registered by a brush on the end of the rod. The movements cannot, for the reasons given, have been due to rotation, hence, by a process of exclusion, we must admit that they are in part lateral. I assume, of course, that no error has crept in from unnoticed movements of the humerus. It is not to be inferred, however, that any lateral movement at the elbow is a perfectly simple one. The want of accurate coaptation of the articular surfaces renders it very unlikely. Two points, I think, are established by these simple experiments,—1st, that the ulna does not rotate; 2nd, that it has a lateral movement. It may be added that rotation of the ulna would demand a new theory of the shape and function of articular surfaces.

DISSECTION OF A DOUBLE MONSTER (EPIGNATHUS).

By ALEX. HILL, M.A., M.B., *Fellow of Downing College, and Demonstrator of Anatomy in the University of Cambridge.*

I AM indebted to Dr Sunderland of Thaxted, Essex, in whose practice the case occurred, for the specimen of epignathus about to be described.

There was nothing in the history of gestation worth remarking as bearing upon the case. Nor does the specimen itself offer for description any features which do not occur in one or other of the cases already on record, unless it be, perhaps, the extreme simplicity of its general formation, which makes it easy to determine the exact relation between the two parts of the double monster. On this account, especially as the condition of epignathus has been held to throw very considerable light upon the mode of formation of all double monsters, I considered the specimen to merit careful dissection and description.

The autosite is a well-developed seven months' female foetus, in all respects normal.

The parasitic twin consists of a lobulated mass projecting from the mouth and anterior nares; of which, it is a noteworthy fact, it produces hardly any dilation or distortion.

The peduncle measures rather less than 1 cm. in diameter, and is attached only to the basi-sphenoid and posterior border of the vomer. The total size of the depending mass is about equal to that of the head of the other foetus. It consists of three large and half a dozen small cotyledons. Of these, the largest (7 cm. long by 5 cm. broad) presents a superficial resemblance to an ill-formed foetal head, with mouth, tongue, and somewhat hairy scalp; but after careful dissection I came to the conclusion that this resemblance is only accidental. It contains a central mass of bone, quite irregular in form and full of cysts.

One of the smaller cotyledons reproduces this appearance in a less obvious form.

Another mass (3 cm. by 2.5 cm.) is covered only by a very delicate transparent membrane, and consists of an embryonal

form of liver—the columns of liver cells being surrounded by much connective tissue, and the whole richly supplied with blood.

A lobule, with very narrow stalk, projects from each nostril—the larger of the two of about the size of a horse-chestnut. These, like the greater part of the rest of the parasite, consist of jelly-like embryonic tissue, covered by well-formed skin, with hair follicles, sebaceous and sweat glands, and presenting much more adult type than the skin of a normal foetus. With the exception of the skin, the tissues, in their minute structure, suggest hasty imperfect formation.

A considerable artery is found in the peduncle, taking origin apparently from one of the pharyngeal arteries. I did not determine its exact source, as I was anxious not to destroy the specimen for the museum. In addition to this, however, a small artery descends through the open pituitary canal from the sella turcica. It is a branch of the left common carotid, connected also, as it appears to me, with a very minute branch from the right. Beneath the basi-sphenoid it breaks into small branches, which run into the peduncle; I was unable to determine whether or not they anastomose with the main peduncular artery. The canal in the basi-sphenoid is merely large enough to transmit this small artery, and the parasite is in no other way connected with the interior of the skull. This intracranial blood supply connects it with a certain number of cases already described, in which the whole stalk descends through the basis cranii, and is of extreme interest in connection with the theories which have been put forth to explain the formation of epignathus. The brain of the autosite, in the present case, including the hypophysis cerebri, is perfectly normal.

The terms used in this description imply that I regard the monster as formed of two foetuses, one normally developed, the other arrested and distorted. Pathologists are not, however, agreed as to the morphological significance of the parasite. No one would contend now-a-days that it is a separate "individual," and the whole monster the product of two distinct ova which have become fused together, but most would regard it as the product of an embryo, which had an existence separate from that of the embryo from which the autosite has grown in the

single ovum. Förster (*Missbildung*, p. 27) would only have it regarded as a "parasite or foetus in foetu" if it contains distinct organs, such as extremities or viscera. Whether our collection of liver-cells entitle it to take this rank according to his definition I do not know.

It does not appear to me, however, that the question as to whether the parasite is or is not to be regarded as morphologically a foetus, is of so much importance as is generally supposed; for if we take a survey of all the various forms of double monstrosity, from the Siamese twins and double-headed Nightingale down to the most degraded form of acardiacus or sacral teratoma on the one hand, or the simplest reduplication of a limb or a digit on the other, we have, in either case, a continuous series; and it is as unnecessary to suppose, in the case of a perfect double monster, that the two embryos which compose it were at any period completely separate, as it is in the case of a reduplicated digit. The more probable explanation of the origin of all forms of double monstrosity is, that growth, which usually proceeds along a single line, proceeds along two parallel, as far as we can trace them back. That the parallelism cannot have existed from the beginning is obvious; there must have been a point of divergence however remote. Gerlach¹ conceived that it might be possible, by limiting the nutritive changes which occur in the ovum to certain regions, to determine the situation and form of the primitive groove, and with this, of the whole embryo. He restricted the respiration of the ovum to a Y-shaped area, by varnishing over the rest of the (hen's) egg, and believes that in this way he produced artificially a duplicitas anterior and other malformations. W. Roux² has, however, shown that the plane of the first cleavage of the ovum, and hence of the axis, is constant for the frog's egg. From the first it is independent of external causes. Possibly, as Roux suggests, it is determined by the direction of conjugation of the male and female pronuclei. Roux also points out that his observations militate strongly against the possibility of artificial production

¹ Ueber die kunstliche Erzeugung von Doppelbildungen beim Hühnchen. *Sitzungsber. d. Phys. med. Societät zu Erlangen*, von 8 Nov. 1880.

² Ueber die Zeit der Bestimmung der Hauptrichtungen d's Froschembryo, Leipzig, 1883.

of double monsters, as well as against Ahlfeld's theory (to which reference will be made immediately). Scanty as is the experimental evidence, many general considerations, as for instance the hereditary predisposition to the minor forms of double growth, would lead us to conclude that the tendency to double formation is inherent in the ovum at a very early period.

Schultze, in his article (*Ueber anomale Duplicität der Axenorgane*, *Virchow's Archiv*, vii.) first insisted upon this double growth. Leuckart (*de monstribus eorumque causis et ortu*) recognised that all the forms of double monstrosity affecting the axis of the embryo could be resolved into three classes,—anterior, posterior, and parallel duplicity,—but considers them to be due to excess of tissue-forming material, abnormal enlargement, and cleavage.

Schultze agrees with Leuckart as to his three ground forms, but considers them to arise "neither through fusion nor cleavage, but through original formation."

Schultze refers to the condition of epignathus, and considers it as a form of doubling of the third class (*duplicitas parallela*), but does not seem to understand by the term "epignathus," anything more than the attachment of a rudimentary foetus to the jaws of a perfect one, nor to be aware of the existence of such cases as the one I have described, in which the stalk of the parasite adheres only to the basis cranii of the autosite.

Referring, however, to the similar condition of the posterior extremity of the body in pygodidymus, which he places in the first class (*duplicitas anterior*), he supposes that the two adherent embryos lay upon the yolk in the same straight line with their heads turned in opposite directions. "That one foetus early fell behind in development, before the tails were raised above the blastoderm, in which case the other foetus would outgrow it with its tail, upon the upper or under surface of which the first foetus would come to rest. If the first foetus rested upon the upper surface of the second, it would come to be shut up in the general coverings on the back of the sacrum; if it lay on the anterior surface (an der vorderen Fläche) of the sacrum, it would come to be shut up in the cavity of the pelvis. The outgrowing of the larger foetus over the other is of such a kind one would suppose, that the strongly developing tail raises in front of it a fold

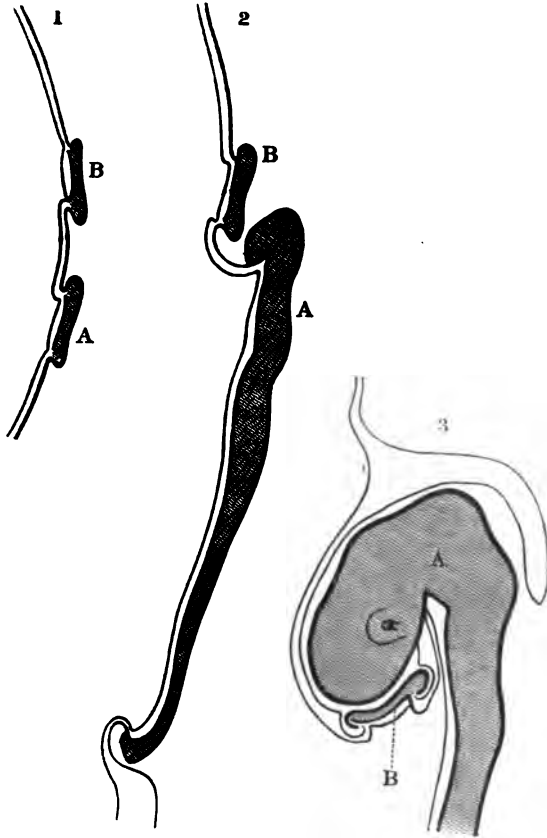
of the epiblast (des animalen Blattes), close up against which lies the smaller foetus, with the visceral and neural layers belonging to it. When the rudimentary foetus contains intestinal structures, it follows that the hypoblast (vegetative Blatt) takes part in the formation of this fold."

It is easy to catch the general drift of this theory, but when we attempt to apply it in detail to the explanation of any particular case of pygodidymus, we find that it affords us very little assistance. It is impossible to conceive of changes in position of two embryos originally lying side by side, such as would result in the one traversing the epiblast of the other, and coming to be attached to a deeply-lying mesoblastic structure like the sacrum, either beneath the gluteal muscles or within the cavity of the pelvis. Nor does there appear to be any reason for separating the sacral teratomata from various cases of *inclusio abdominalis* with which they are connected by transitional forms; if, however, it were attempted to apply the same explanation to these latter, the difficulty would be increased by the necessity of following the parasite in its passage through epiblast and mesoblast to hypoblast.

Dr Ahlfeld, in his exhaustive paper (*Archiv für Gynäkologie*, Bd. vii., 1875), collects twenty-six cases of epignathus from medical literature, and gives figures of the greater number. More recently, in his work *Die Missbildungen des Menschen*, he states that he now knows of as many as forty cases. He applies Schultze's theory of pygodidymus to this form of monstrosity also, illustrating the explanation with woodcuts, which I here reproduce.

"We suppose," he says, "that the completely separate embryonic areas lie on a single egg, in such a way that the two embryonal axes, the heads of which are turned towards one another, are in the same straight line. The distance apart of the two embryos must be sufficient to allow of their both rising up on the blastoderm without interfering with one another. Supposing A grows quickly while B remains small, it will follow, provided the distance between the embryos is not too small, that B soon comes to lie beneath the anterior cerebral vesicle of A, and later still in the funnel which points at the infundibulum (in which in the same way the end of the fore-gut is tucked in), and thus

touches the infundibulum with its apex. Thus B lies between the hinder layer of the fore-brain and the anterior layer of the fore-gut. With the brain vesicles in front of it, B grows in front of the cavity of the fore-gut, and may come to reach the end of the space, its anterior end being compelled to assume a pointed form owing to its relation to surrounding parts."



As remarked about the pygodidymus theory of Schultze, it is easy to follow the general lines indicated in Ahlfeld's explanation, but very difficult to work out the idea in detail. So many hypotheses are involved as to remove it almost beyond the range of working theories. In the first place, an immense disproportion in growth between the two embryos must be imagined,

sufficient to allow of the one embryo receiving the other into its stomodæum, the inequality appearing at a very early period, and being most marked, indeed, at a time when the two embryos are lying side by side under exactly similar conditions upon the yolk. It is difficult, if not impossible, to account for this disparity, which would need to be peculiar to the embryos themselves; one would be more inclined to imagine that the two embryos, being placed under exactly similar conditions, and starting with the same forces tending to growth, would enter into a struggle for the common food supply, only to be terminated by the one obtaining a mechanical advantage over the other, which would reduce the latter to a condition of dependence, and finally of parasitism. A study of the histological structure of the parasite bears out this supposition, its tissues exhibiting the clearest evidence of hasty, imperfect formation, as if the potentiality of growth had always been there, but only recently had the restraining conditions been removed and tissue-formation allowed to proceed. The appearance of the autosite further indicates this: jaws, palate, septum nasi, are all perfect and very little distorted; the principal growth of the parasite must have occurred, one would suppose, quite recently, and subsequently to the formation of these organs. In the second place, although in the diagrams the position of the parasite B in the funnel (trichter) is intelligible enough, it is important to remember that the conditions are here unduly simplified. As a matter of fact, a very considerable quantity of mesoblast everywhere intervenes between the peripheral epiblast and the basis cranii, and the parasite could only traverse this and reach a position immediately beneath the sella turcica by being engulfed into the primitive buccal cavity, and even into the pituitary diverticulum of the buccal cavity. This being the case, it is difficult to account for the parasite travelling so far, and not taking up its permanent position by attaching itself to some other part of the wall of the buccal cavity, to the inside of the cheek or nasal cavities, or to the gums, for instance. Such an attachment is described in certain cases, but that it is a secondary one is indicated by the fact that it is the hard palate which is most frequently selected.

The artery which in the case above described passes down

from the internal carotid, may have taken advantage merely of the open pituitary canal to reinforce the pharyngeal arteries which supply the mass of the parasite, or may possibly have a much wider significance, for, although in only a few cases is the attachment of the parasite carefully recorded, irregularities in the basis cranii are noted in the following:—In Wegelin's case the stalk goes through a hole in the sella turcica, and reaches as far forwards as the crista galli. In Rippmann's case a part of the parasite is intracranial, the connecting-stalk passing through the pituitary canal; the hypophysis cerebri is wanting. In Arnold's case a part of the tumour is intracranial, being connected with the extracranial part by a stalk 1 cm. thick, which pierces the basis cranii. The intracranial portion and the stalk are described as resembling white brain matter, but the hypophysis is not mentioned. In J. Baart de la Faille's first case the stalk pierces the sella turcica from below upwards; the hypophysis is wanting. In his second case the stalk also perforates the sella turcica, going to be attached to the anterior clinoid processes; the brain was too rotten for investigation. In ten other cases only is the origin of the peduncle described with any attempt at detail, and in five of these there is attachment to the pharynx-wall. Only in one (Ahlfeld's) is it distinctly stated that the basis cranii is absolutely normal, and it is possible that, had attention been directed to this point, traces of an original intracranial attachment would have been discovered in some of the other cases.

It would appear to me that, in his explanation of the sacral teratomata, Schultze has departed from his own axiom "neither through fusion nor cleavage but through original formation," and that Ahlfeld has introduced into his ingenious adaptation of Schultze's theory certain by no means probable hypotheses, and at the same time overlooked some of the most striking characteristics of the condition of epiguathus.

THE RELATION OF THE ALVEOLAR FORM OF CLEFT
PALATE TO THE INCISOR TEETH AND THE
INTERMAXILLARY BONES. By Professor W.
TURNER, M.B., F.R.S.

(Communicated to the Royal Society of Edinburgh, December 15, 1884.)

IN an essay on the intermaxillary bone published in 1786, the illustrious Goethe, by the recognition of a suture on the palatal aspect of the upper jaw, extending from the incisive foramen to the interval between the canine and lateral incisor tooth, and of a prolongation of the same suture into the naso-palatine canal, determined the presence of this bone on each side of the human upper jaw. In a subsequent essay, published in 1819, he cited other facts in support of this position, and stated that in hare-lip the incisive or intermaxillary bone is separated from the superior maxilla, and the suture between the two bones remains open. Since that time it has been the current doctrine that the lateral cleft in the alveolar border of the jaw, which so frequently accompanies a hare-lip, marks the separation between the intermaxillary and superior maxillary elements of the human upper jaw.

In an essay published in 1879,¹ Dr Paul Albrecht traversed this conclusion of Goethe's. From the examination of the skull of a young horse, with a double hare-lip and alveolar cleft, of the skulls of two calves with lateral alveolar clefts, and of similar malformations in the human upper jaw, he came to the conclusion that the cleft was not between the intermaxilla and superior maxilla, but was intra-incisive in position, and co-existed with the usual suture of articulation between the superior maxilla (exognathion) and the intermaxilla. He considered that the explanation of this condition was to be looked for in the presence during earlier stages of development of two intermaxillary bones on each side, a mesial (endognathion) and a

¹ Die morphologische Bedeutung der seitlichen Kieferspaltte and die wahrscheinliche Existenz von vier Zwischenkiefern bei der Säugethieren, *Zoologischer Anzeiger*, 1879, p. 207.

lateral (mesognathion), and that the alveolar cleft was an open state of the suture (endo-mesognathic suture) which ought to have connected them together. In support of this position he refers to observations by Albinus, Autenrieth, J. F. Meckel, Leuckart and himself on the existence of the remains of a suture in many hard palates, situated in the area between the mesial palatal suture and the maxillo-intermaxillary (meso-exognathic) suture.

Since the publication of this essay Dr Albrecht has written a number of papers on the same subject, and has accumulated many additional observations in support of his views.¹ As he has done me the favour of presenting me with copies of these papers, I have been able to make myself acquainted with his opinions on this interesting topic, and have tested his statements by an examination of such material as I have been able to obtain access to.

I propose in this communication to give an account of some observations which I have made on this interesting branch of teratological anatomy. My observations fall under the following heads:—

A. The examination of an extensive series of casts of the roof of the mouth in cases of cleft palate, where the cleft had extended forwards through the alveolar border of the jaw, either on one or on both sides. For the opportunity of examining these casts, and for information regarding the cases, I have to express my obligations to my colleagues, Professors Annandale and Chiene; to Dr John Smith, President of the Royal College of Surgeons, Edinburgh; Dr Joseph Bell, Senior Surgeon, Edinburgh Royal Infirmary; W. Bowman Macleod, Esq., L.D.S., Dean of the Dental School; and Andrew Wilson, Esq., L.D.S., Lecturer on Dental Anatomy, Edinburgh.

B. The examination of a large number of human hard palates

¹ Sur les 4 os intermaxillaires, &c.; Communication faite à la *Soc. d'Anthropologie de Bruxelles*, Brussels, 1883; sur la Fente maxillaire et les 4 os intermaxillaires de l'Ornithorynque, Communication faite à la *Soc. d'Anatomie Pathologique de Bruxelles*, 1883; Erwiderung auf Prof. H. v. Meyer, *Deutsche Zeitsch. für Chirurgie*, 1884; Die morphologische Bedeutung der Kiefer-, Lippen- und Gesichtspalten, *Langenbeck's Archiv*, Bd. xxi. Heft. 2; under the same title in *Centralblatt für Chirurgie*, 1844, No. 23; Ueber die Zahl der Zähne bei den Hasenscharten Kieferspalt in *Centralblatt für Chirurgie*, 1884, No. 32.

in the Anatomical Museum of the University, where there was no cleft, with the view of ascertaining if any sign was visible to indicate the division of the intermaxillary region of the upper jaw into a mesial and a lateral portion.

A. Casts of the Roof of the Mouth in Alveolar Cleft Palate.—

In the absence of preparations of cleft palate, either in the dry bones or in spirit-preserved specimens, carefully prepared casts of the roof of the mouth are of service, as they show not only the position and direction of the cleft, but the number, arrangement, and forms of the teeth, and the relation which the alveolar cleft has to the teeth in the incisor and canine series. They do not, of course, enable one to state with absolute precision the particular part of the jaw in which the alveolar fissure is situated, and still less do they permit one to determine if a maxillo-intermaxillary suture coexists with the alveolar cleft. But, as in the living mouth itself, the relations of the teeth to the cleft can be accurately determined; also, in so far as the development of the incisor teeth is to be associated with the position of the intermaxillary elements of the human upper jaw, an estimate can be formed from them of the position and extent of the intermaxillary bones, and of their relations to the superior maxilla.

In the course of the description of the casts I shall have to refer to the presence or absence of a tooth in the dentary series in the interval between the canine tooth and the alveolar cleft. To avoid mixing theoretical considerations with the description, I shall call this tooth *precanine*, from its position,—a convenient term which has also been employed by Dr Albrecht.

1. *Left Alveolar and Mesial Palatal Cleft.*—Cast from the museum of Professor Annandale. The patient was *æt.* 15, and was operated on in 1864.¹ On each side the 1st and 2nd permanent molars, both the bicuspid and the permanent canines were erupted. Between the right canine and the cleft the right lateral incisor and the two central incisors were in position. Between the left canine and the cleft was situated the crown of a well grown *precanine* tooth, which bounded the cleft on its outer side.

2. *Left Alveolar and Mesial Palatal Cleft.*—Cast from the

¹ Operation described by Mr Annandale in *Edin. Med. Jour.*, Jan. 1865.

museum of Professor Annandale. Adult. On each side all the true molars, the bicuspid, and the permanent canine were erupted. Between the right canine and the cleft were two incisor teeth, which were apparently the central incisors. On the left, *i.e.*, outer side, of the cleft, but on the palatal side of the permanent canine, was the crown of a well grown tooth, which obviously represented the left *precanine*, although it was displaced out of its regular order in the dentary arcade, and consequently was not so close to the cleft as in the preceding specimen.

3. *Left Alveolar and Mesial Palatal Cleft*.—Cast from the collection of Dr John Smith. Adult. On each side all the true molars were erupted, on the right side both bicuspid, on the left one bicuspid, also the permanent canine on each side. Between the right canine and the cleft were four incisors, a left and right central, and two right laterals. It is possible that the lateral incisor immediately in front of the right canine was a retained milk incisor. A small *precanine* was situated immediately in front of the left canine and close to the cleft.

4. *Left Alveolar and Mesial Palatal Cleft*.—Cast from the museum of Mr Bowman Macleod, L.D.S. Adult. On each side all the true molars, bicuspid, and the permanent canine were erupted. Three incisor teeth had been situated between the right canine and the cleft, but the right lateral incisor had been extracted. The crown of a small *precanine*, which projected beyond the gum like a little tubercle, was situated immediately in front of the left canine and close to the cleft.

5. *Left Alveolar and Mesial Palatal Cleft*.—Cast in the museum of the Dental Hospital and School, London.¹ On each side the 1st and 2nd true molars, both bicuspid and the permanent canine were in place. Between the right canine and the cleft were the right lateral and both central incisors, and the left central incisor projected almost horizontally forwards. The small crown of a left *precanine* occupied the interval between the left canine and the cleft, and it projected almost horizontally forwards and inwards about half way across the cleft.

6. *Left Alveolar and Mesial Palatal Cleft*.—Cast from the

¹ For the opportunity of examining the copy of the cast of this and the other casts in the Museum of the London Dental School, described in this communication, I am indebted to W. Bowman Macleod, Esq., L.D.S.

museum of Professor Annandale. Adult. All the true molars, the bicuspid, and both the canines were erupted. Between the right canine and the cleft were two incisor teeth, and as there was a diastema between the cleft and the incisor on its mesial side, it is possible that another incisor may have been extracted. On the palatal side of the left canine was the crown of a well-developed tooth, which projected vertically and parallel to the canine, and which, from its size, was obviously not a milk tooth. It was close to the alveolar cleft, but the crown of the canine, from being a little bigger, overlapped obliquely this tooth, so as to approach closer to the cleft. I regard this tooth as a *precanine*, displaced from its proper order in the dentary arcade.

7. *Left Alveolar and Mesial Palatal Cleft*.—Cast in the museum of the Dental Hospital, London. Transitional dentition; first permanent molar, all the milk molars and canines were erupted. Two permanent incisors were cutting the gum between the right canine and the cleft. A milk *precanine* was situated between the left milk canine and the cleft, and close to the cleft.

8. *Left Alveolar and Mesial Palatal Cleft*.—Cast from the museum of Professor Annandale. Permanent dentition. There were apparently four incisors between the right canine and the cleft; but the cast wanted definition in that region. The left canine came up to the cleft, and no *precanine* was interposed.

9. *Right Alveolar and Mesial Palatal Cleft*.—Cast in the museum of Professor Chiene. Child. First permanent molar and 1st bicuspid erupted on each side; 2nd milk molar in place, also the milk canines. The two milk central incisors had been shed, and the permanent incisors were appearing in their place, but the left lateral milk incisor was in front of the corresponding canine. Between the right milk canine and the cleft was the small crown of a milk *precanine*, which projected close up to the cleft.

10. *Right Alveolar and Mesial Palatal Cleft*.—Cast in the museum of Mr Bowman Macleod, L.D.S. Youth, æt. 16. On each side the 1st and 2nd permanent molars, both bicuspid and the permanent canines were erupted. Three permanent incisors had been present in the interval between the left canine and the cleft, but the right central incisor had been extracted

before the cast was taken. Immediately to the right side of, i.e., external to the cleft, was a tooth which obviously represented a right *precanine*, though it was displaced from its proper order in the dentary arcade, and had erupted on the palatal side of the right canine.

11. *Right Alveolar and Mesial Palatal Cleft*.—Cast in the museum of Mr Andrew Wilson, L.D.S. Permanent dentition. The molars, bicuspid, and canines on each side were erupted. Between the left canine and the cleft were the two central incisors and the left lateral incisor. Between the right canine and the cleft was a *precanine*, the crown of which was small, and overlapped the cleft. It was somewhat displaced from its proper order in the dentary arcade, and was in part situated on the palatal side of the right canine.

12. *Right Alveolar and Mesial Palatal Cleft*.—Cast in the museum of Professor Annandale. Transitional dentition. No *precanine* was situated in the interval between the right canine and the cleft.

13. *Double Alveolar and Mesial Palatal Cleft*.—This very interesting case occurred in the practice of Dr Joseph Bell, who removed the projecting intermaxillaries with their incisor teeth. Before this operation, a cast of the roof of the mouth was taken by Mr A. Wilson, L.D.S., who has kindly lent me both the cast and intermaxillary bones for examination. The patient was about 17 years of age, and presented on each side a deep alveolar cleft which joined posteriorly a mesial palatal cleft. The projecting, isolated, and mesially-placed intermaxillaries were fused together into a single bone, and contained four incisor teeth, the two central of which were directed vertically and with their crowns honeycombed; whilst the two lateral projected almost horizontally outwards, each at its own side. Behind the cleft on each side were, from behind forwards, the 1st and 2nd permanent molars, though the crown of the 1st was decayed, two bicuspid, and the permanent canine, but on the left side the temporary canine was still present in the dentary arcade between the permanent canine and 1st bicuspid. On each side, also, a small *precanine* tooth projected about 4 mm. beyond the gum in the interval between the permanent canine and the alveolar cleft, and close to the outer side of the cleft.

14. *Double Alveolar and Mesial Palatal Cleft*.—Cast from the museum of Mr Bowman Macleod, L.D.S. The intermaxillary bones had been removed during early infancy. The cast was taken when the permanent molars, bicusps, and canines had erupted. No *precanine* tooth was present on either side, and, as the intermaxillaries had been removed, there were no representatives of incisor teeth.

15. *Double Alveolar and Mesial Palatal Cleft*.—Cast in the museum of the Dental Hospital, London. The conjoined and isolated intermaxillaries showed no evidence of incisor teeth. The first permanent molar on each side, both the milk molars and milk canine, were erupted. On each side a distinct *precanine* tooth was situated between the milk canine and the cleft.

The casts above described are fifteen in number, and of these eight are left-sided, four right-sided, and three double clefts. The greater frequency of the alveolar cleft on the left than on the right side is in accordance with previous observations on the same subject, for Th. Kölliker states¹ that of 165 cases of one-sided cleft recorded in teratological literature, 113 were on the left side, and only 52 on the right side. It would seem, therefore, as if in this region of the face the development of both the bones and soft parts is more likely to be incomplete on the left than on the right side of the mesial plane.

In the eight specimens of left alveolar cleft with one exception, in the four right alveolar clefts with one exception, and in the three double clefts also with one exception, a *precanine* tooth existed in the interval between the canine and the cleft, although it was in three cases displaced to the palatal side of the canine, so that in only three of the fifteen specimens did the canine tooth form the immediate boundary of the cleft on its outer side. In the specimens of single cleft in which a *precanine* was present on the side on which the cleft existed, two, three, and in one case four incisors were situated in the intermaxillary region between the cleft and the canine on the opposite side. In one of the cases of double cleft,

¹ "Ueber das Os intermaxillare des Menschen und die Anatomie der Hasenscharts und des Wolfsrachsens," *Nova acta der Leop. Carol. Akad. der Naturforschen*, Bd. xliii., Halle, 1882.

four large incisors projected from the conjoined intermaxillaries, and, in addition, a precanine tooth was present on each side.

In his elaborate and important memoir on the development and anatomy of the intermaxillary bones, Dr Th. Kölliker has given an account of the relations of the teeth to the alveolar fissure or fissures in forty-nine wet or dry preparations which he has examined in several of the museums in Germany. Twenty-eight of these specimens had a cleft on both sides, sixteen had the cleft on the left side only, and five on the right.

In the sixteen left-sided clefts there was no tooth in two specimens between the canine and the cleft. In fourteen specimens such a precanine tooth was present; in nine of these cases this precanine coexisted with three incisors situated on the opposite side of the cleft, so that, including the precanine, the incisors had the normal number, four; whilst in the remaining five cases this precanine was an additional tooth on the side on which the cleft occurred, and the number of incisors was raised to five.

In the five right-sided clefts there was no tooth in two specimens between the canine and the cleft; in one a precanine coexisted with three incisors on the opposite side of the cleft; in one the precanine was an additional tooth on the side on which the cleft occurred, and the number of incisors was raised to five; in one very remarkable specimen no less than three precanine teeth were interposed between the right canine and the cleft, and four incisors were situated between the cleft and the left canine tooth, so that the teeth lying between the opposite canines were seven in number.

In the twenty-eight specimens of double cleft, there was no tooth in six specimens between the canines and the clefts; in three specimens a precanine was present on one side only; in nineteen specimens the precanine was present on both sides. In some of these nineteen specimens the precanine brought the incisors up to the normal number, four; but in other specimens it formed an additional tooth in the incisor series, and in five specimens there were six teeth interposed between the opposite canines, viz., four in the isolated and projecting intermaxillary

bones, and one on each side between the canine tooth and the cleft.¹

Dr Kölliker's forty-nine preparations and my fifteen casts make in all sixty-four specimens in which the relations of the alveolar cleft to the teeth have been definitely observed. These specimens resolve themselves into two groups—*a*, one in which no precanine tooth intervened between the canine and the cleft, and in this group were thirteen specimens; *b*, one in which a precanine was situated between the canine and the cleft, and this consisted of fifty-one specimens. Obviously, therefore, much the larger number of persons with the alveolar form of cleft palate possess a tooth in front of the canine, which is cut off from the incisor series of teeth by the gap in the border of the jaw. The question therefore arises as to the nature of this precanine tooth.

A well-known principle has long been accepted by anatomists, that all the teeth situated in front of the canines are incisor teeth, and that all those teeth which occupy this position in the upper jaw are implanted in the intermaxillary bones. Hence, the expressions incisor and intermaxillary are synonymous terms for these teeth in the upper jaw. If this principle be applied to the determination of the nature of the precanine tooth in alveolar cleft palate it would have to be called an incisor tooth. But the precanine is cut off from the other incisor teeth by the cleft in the border of the jaw, and it would therefore follow that the intermaxillary bone would also be divided into an inner and an outer portion by the cleft, that the precanine tooth would be situated in the outer division of that bone, and that the cleft would lie, therefore, between the two divisions of the intermaxilla and not between the inter- and superior maxilla. This is the position assumed by Dr Albrecht, and granting the accuracy of the principle that all precanine teeth are necessarily intermaxillary in their implantation, the specimens belonging to group *b* might all be cited in support of his position. The specimens of double cleft palate in which four incisor teeth

¹ Professor Humphry, in his well-known treatise on the Human Skeleton, has figured (plate xiii. fig. 1) a specimen of double cleft palate in the human skull. On each side a precanine tooth had erupted, which he describes as a supernumerary canine.

projected from the intermaxillary bones (case 13), and a precanine tooth also existed on each side, are in no way opposed to this position, although the presence of the normal number of incisors in that region, which is undoubtedly intermaxillary, might at a first glance seem to be so. For not only is six a very common number of upper incisors in various mammals,¹ but, as is well known to dental surgeons, three incisor teeth are sometimes developed on each side of the human upper jaw when there is no alveolar cleft. I have now before me the casts of two otherwise normal palates taken from different persons by Mr Andrew Wilson, L.D.S.—one with the milk, the other with the permanent dentition, in each of which six upper incisor teeth had been developed. The question therefore naturally arises, Which of these teeth is suppressed in the normal incisor dentition in man? Some light is thrown on this question by these cases of alveolar cleft. In the cases of double cleft, with two incisors in each half of the projecting intermaxillaries, these teeth would be in dental notation In^1 , In^2 , whilst the precanine would be In^3 . But in many cases of alveolar cleft, more especially when it is one-sided, only one incisor tooth exists between the mesial suture and the cleft, whilst a precanine is present in its outer side. The precanine, as in the preceding example, would be In^3 , whilst the incisor situated mesially to the cleft would in the majority, if not all, of cases without doubt be In^1 ; the suppressed incisor therefore would be In^2 , and it is not unlikely that in normal human dentition the incisor which does not develop is also In^2 .

This view of the homology of the precanine tooth and of the normal lateral incisor—viz., that it is In^3 —is also advocated by Dr Albrecht.² Dr Th. Kölliker, however, has not apparently formed any exact conception of its homology; for although he sometimes refers to it as In^3 , at others he speaks as if it repre-

¹ From the investigations of Mr Spence Bate, published in *Trans. Odontological Soc. London*, vol. v., it would appear that in the mole, *Talpa europæa*, four teeth are developed in each intermaxillary bone, an example, therefore, in a placental mammal of eight upper incisors, though Mr Spence Bate himself speaks of the outermost incisor as a canine tooth. The case related by Dr Th. Kölliker, in which seven teeth were situated in the human upper jaw between the opposite canines, is therefore an approximation to the arrangement in the mole.

² *Sur les 4 os intermaxillaires, &c.*, Bruxelles, 1883.

sented the ordinary lateral incisor, which incisor he obviously regards as a different tooth from *In* ³.

Moreover, Kölliker disputes the position that the relation of the teeth to the cleft in alveolar cleft palate can enable us to determine whether the cleft is a gap in the intermaxillary bone or a cleft between the intermaxilla and the superior maxilla. For the teeth and the jaw are, he says, quite independent of each other in the early stages of their development, and only become related to each other secondarily, as the processes of tooth formation and bone formation respectively advance. The independence of these two processes in their early stages will, I should say, be generally admitted. No one probably would, from the study merely of such a series of casts as I have described, without at the same time having had the opportunity of examining the jaws, have come to the conclusion that the cleft was not, as Goethe taught, in the maxillo-intermaxillary interval, but, as Albrecht now teaches, within the intermaxillary itself. Though the fact that, in so large a proportion of the casts, an incisor tooth was situated on the canine side of the cleft could scarcely be without some significance, and from the frequency of its occurrence, should not be regarded as a mere accidental displacement of a tooth germ.

Albrecht has, however, had the advantage of examining several skulls in which the alveolar cleft was seen to separate the intermaxilla into an inner and an outer part, each carrying its appropriate incisor or incisors. In addition to the skulls of the horse and the calves referred to in his first essay on this subject, he has since described and figured an adult human skull in the University of Kiel, in which a right cleft existed in the corresponding intermaxilla, and the right maxillo-intermaxillary suture co-existed with and was quite distinct from the cleft; a new-born infant with double cleft, in which the same suture was present; the jaw of a child about one year old, in the museum at Ghent, in which, with a left cleft in the corresponding intermaxilla, a left maxillo-premaxillary suture was present. In all these cases the part of the intermaxilla which was situated to the outside of the cleft contained the socket for the precanine incisor. One must therefore accept the conclusion, that the anatomical evidence justifies the statement that, in a proportion of cases of

alveolar cleft palate, the cleft lies within the intermaxilla, the cleft coexists with the maxillo-intermaxillary suture, and an incisor tooth is situated in the interval between the cleft and the canine of the same side.

But I have stated in an earlier part of this paper that there is a group of cases (*a*) of alveolar cleft (*ante*, p. 206) in which no precanine tooth intervened between the canine and the cleft. In some of these only two or three incisors were present, but in others four incisors were situated in the region between the cleft and the opposite canine. It is not improbable that these cases may be examples of a cleft occurring in the plane of the maxillo-intermaxillary suture, and not within the intermaxilla itself. Wherever a suture exists, there, of course, a possibility of an imperfect union of the two bones may arise. Should the bones remain separate, and should the want of union be accompanied by a non-closure of the superjacent soft parts, then the imperfect development would lead to the production of a cleft in the alveolar region, and the theory of Goethe would therefore be applicable to such cases.

For many years the existence of the intermaxillary part of the human upper jaw as an element distinct from the superior maxilla rested rather on general anatomical considerations than on embryological data. Even so recently as December 1858, M. Em. Rousseau, in a paper in the *Comptes Rendus*, was of opinion that, in the normal ossification of the upper jaw, there was no evidence that the intermaxilla had a centre of ossification distinct from the superior maxilla, and a similar view was expressed by Dr Cleland.¹ Dr Joseph Leidy had, however, published some years previously² a short account of a dissection which he had made of a human embryo 1 inch 11 lines in length from vertex to heel, and which he believed to be nine or ten weeks old. He found the intermaxilla in apposition with the superior maxilla for $1\frac{3}{4}$ ds of a line; but they were easily separable at this period along the plane of a suture which passed through the alveolar ridge between the incisor and canine alveoli, and which divided the nasal process into two nearly equal por-

¹ "On the Relations of the Vomer, Ethmoid and Intermaxillary Bones," *Phil. Trans.*, 1861.

² *Proc. Acad. Nat. Sc.*, Philadelphia, 1848-49, p. 145.

tions. Dr Leidy's observations did not, probably owing to the periodical in which they appeared not having much circulation in Europe, for many years attract attention. Mr G. W. Callender furnished some important observations¹ on this subject several years afterwards. He described in a foetus, 2·3 inches long, a smooth plate of bone as passing forwards from the base of the nasal process of the superior maxilla, and he called this plate the "incisor process." The intermaxilla, he stated, "consists of deposits of bone about the posterior edge of the incisor process, which subsequently grow down to form the plate of bone on the inner side of the middle incisor socket, and the posterior wall of the incisor sockets below and internal to the course of the incisor branches of the dental nerve." In a foetus 4·4 inches long, "the intermaxilla is completely formed, and may be traced as a distinct bone." It forms the front of the palate, and fills up the notch between the incisor and palatal processes of the superior maxilla; it also possesses "a narrower portion, which ascends and fits by a convex surface into the groove of the nasal process, ending above at the ridge for the turbinate bone, part of which ridge it forms." Callender accounts for the absence of all trace of the human intermaxilla on the facial aspect of the upper jaw by the bone being shut off from the face by the nasal and incisor processes of the superior maxilla. "It is joined to the superior maxilla during the latter part of the fifth or beginning of the sixth month." But the independence of the intermaxilla in its earliest stage has also been demonstrated by Dr Th. Kölliker in his essay already so frequently referred to. By adopting a process very similar to that recommended a number of years ago by Dr Lionel Beale,² for the purpose of studying the stages of ossification in the early embryo, of rendering the soft tissues transparent by digesting the foetus in a solution of caustic alkali, Kölliker has seen the centres of ossification in the upper jaw without any disturbance of their natural relations. He has described and figured the head of

¹ "The Formation and Early Growth of the Bones of the Human Face," *Phil. Trans.*, 1868.

² Beale's *Archives of Medicine*, vol. i. p. 150, 1859. Dr Beale's formula is eight or ten drops of solution of caustic soda in each ounce of alcohol. A foetus soaked for a few days in this fluid, and then preserved in spirit, forms, he says, a very beautiful preparation.

an embryo at about the eighth week, in which the centre for the intermaxilla was quite separate from that which gave origin to the superior maxilla.

B. *The Hard Palate where there was no Cleft.*—The object of examining the hard palate where there was no cleft was to ascertain if any suture, or the remains of a suture, could be seen in its anterior part, immediately behind the incisor teeth, to indicate that, as Dr Albrecht contends, the incisive or intermaxillary element of the human upper jaw had originally consisted of two bones on each side, a mesial or internal, and a lateral or external.

As is well known, it is not uncommon to find in young human skulls, and less frequently in adult palates, the remains of the incisive suture which Goethe recognised as connecting the intermaxillary element of the upper jaw to the superior maxillary element. Th. Kölliker, who has especially looked into this matter statistically, states that he has seen the maxillo-intermaxillary suture, or the remains of it, ninety-six times in 325 adult crania which he has examined.

The authors cited by Albrecht in his first communication on this subject, Albrecht himself, and, subsequently Professor Hermann v. Meyer, have referred to crania in which the remains of an intra-incisive (endo-mesognathic) suture were also seen; and Albrecht has figured¹ the hard palate of a child about five years old, in which the mesial palatal suture, a pair of lateral maxillo-intermaxillary sutures, and a pair of intra-incisive sutures were visible. The observations which I shall now refer to enable me also to state that a narrow fissure in each intermaxilla, which together apparently represent the remains of a pair of intra-incisive sutures, may occasionally be seen in the hard palates of both young and adult human crania, in conjunction with a pair of maxillo-intermaxillary sutures.

a. Superior maxillæ; milk dentition. A maxillo-intermaxillary suture visible on palate, floor of nose, and nasal aspect of ascending process of superior maxilla. A short intra-incisive fissure on the palatal aspect, branched off from the maxillo-premaxillary suture 2 mm. from the mesial palatal suture, and external to the naso-palatine (incisive) canal; it extended for 2 mm. in the direction of the interval between the central and lateral incisor,

¹ *Deutsche Zeitsch. für Chirurgie*, 1844.

but did not reach the alveolar border. It did not extend through to the nasal surface of the bone.

b. Superior maxillæ; milk dentition. Arrangement similar to that described in a.

c. A similar preparation, but the fissure in the right bone extended for between 4 and 5 mm. on the palatal aspect, and reached the interval between the orifices for the gubernacula of the permanent central and lateral incisor teeth.

d. A similar preparation, where there was only an indication of an intra-incisive fissure scarcely 1 mm. long on the palatal aspect of the upper jaw.

e. Superior maxillæ, in which all the permanent teeth were erupted except the wisdoms. Maxillo-premaxillary suture visible both on the hard palate and on the nasal surface of the bone. An intra-incisive fissure branched off from it, and extended for 2 mm. in the direction of the interval between the central and lateral incisor.

f. Right superior maxilla. All the permanent teeth erupted. The maxillo-premaxillary suture was visible on both the palatal and nasal surfaces, and on the former reached the alveolar border. An intra-incisive fissure arose from it 4 mm. from the mesial palatal suture, and extended for 6 mm., so as to reach the alveolar border a little to the inner side of the septum between the central and lateral incisor. This fissure, as in the other specimens, was not visible on the nasal surface.

The place of origin of the intra-incisive fissure in the majority of the specimens was from the maxillo-premaxillary suture external to the incisive canal, which canal, therefore, on the theory that the intermaxilla consists of an inner and an outer division, would lie in relation to the inner division close to the articulation between it and the superior maxilla. In one instance the intra-incisive fissure penetrated into the naso-palatine canal. Obviously, therefore, some condition arising during the development of the bone determined the origin and direction of the fissure in question.¹

Th. Kölliker, who, as already stated, is opposed to Albrecht's theory of the double constitution of the intermaxilla, has recog-

¹ A detailed description of the naso-palatine canal in man is given by Prof. H. Leboucq in *Archives de Biologie*, vol. ii., 1881.

nised similar fissures on the hard palate as many as five times, he says, in the skulls of thirty children. But he regards these fissures not as sutures, but as vascular furrows connected with the distribution of the anterior palatine vessels. As a rule, however, the intra-incisive fissure in my specimens did not arise from the anterior palatine fossa,¹ but from a definite point in the maxillo-intermaxillary suture on the surface of the hard palate. The intra-incisive fissure corresponded closely in its character with the maxillo-intermaxillary suture, with which it was continuous; so that, as far as one can judge from similarity in appearance, if the latter is a suture, which every one admits, then the former may be fairly regarded as one also.

What is yet wanted, however, in order to give completeness to the evidence of the division of the intermaxillary bone into an inner and an outer part, is the discovery that the intermaxillary bone normally rises from two distinct centres of ossification, one for the inner, the other for the outer part. Of this we have at present no evidence. But, in connection with this matter, we ought not to forget that it is quite recently that the embryological evidence of the origin of the intermaxillary part of the human upper jaw from a centre distinct from that of the superior maxilla has been completed. And yet for nearly a century, on such minor evidence as was advanced by Goethe, viz., the suture on the hard palate extending through to the nasal surface, anatomists have believed and taught that the human upper jaw represented both the superior and intermaxillary bones in any other mammal. Where a question in human embryology hinges upon an examination of parts in a very early stage of development, we often have to wait for many years before an appropriate specimen falls into the hands of a competent observer.

I prefer to call the large foramen in the hard palate behind the incisor teeth the anterior palatine fossa, whilst the lateral foramen opening into it on each side is the incisive or naso-palatine canal, or canal of Stenson, and the two foramina in the mesial suture are the foramina of Scarpa.

THE DUMB-BELL-SHAPED BONE IN THE PALATE
OF *ORNITHORHYNCHUS* COMPARED WITH THE
PRENASAL BONE OF THE PIG.¹ By Professor
W. TURNER, M.B., F.R.S.

As an additional argument in support of his view that the intermaxillary bone consists of an inner, or mesial, and an outer, or lateral part, Dr Albrecht refers to the arrangement of the bones of the beak of *Ornithorhynchus paradoxus*. All anatomists have recognised as intermaxillary bones the pair of bones articulating with the nasals and superior maxillæ, which form the anterior end of the beak of this animal, and which curve inwards in front, but do not meet mesially. Rudolphi described² them as the outer intermaxillaries, and gave the name of inner intermaxillary to an ossicle situated on the palate, and separated from the outer intermaxillary by a considerable interval. J. F. Meckel described this ossicle as an unsymmetrical 8-shaped bone³ attached by membrane to the anterior end of the palatal portion of the superior maxilla, and he also considered it as a division of the intermaxilla. Sir Richard Owen regarded⁴ this detached intermediate bone as a separate centre of ossification of the palatine process of the intermaxillaries. Albrecht has also examined this ossicle, and has pointed out that the incisive or naso-palatine canal opens on each side of it. He considers that its position between these two canals incontestably demonstrates it to be the two internal intermaxillary bones united together, and he calls it *l'os paradoxo*. As this bone is separated on each side from the outer intermaxilla, Albrecht regards the *Ornithorhynchus* as having normally a submucous double maxillary cleft and four intermaxillary bones.

Since reading Albrecht's paper, I have examined both a carefully prepared skull and a recent dissection of the head of

¹ *Sur la Fente maxillaire et les 4 os intermaxillaires de l'Ornithorynque*, Bruxelles, 1833.

² Quoted by Meckel and Albrecht.

³ *System der vergleichenden Anat.*, Bd. 2, Ab. 2, 1825; and *Descr. Anat. Ornithorhynchi paradoxo*, Lipsiæ, 1826.

⁴ "Monotremata" in Todd's *Cyclopædia*, vol. iii.

Ornithorhynchus, with the view of studying the relations of this ossicle. It is exposed by reflecting the mucous membrane of the anterior part of the roof of the mouth. In shape it resembles a dumb-bell, in which the more posterior of the two swellings is larger than the more anterior. It is not a single mesial bone, but consists of two symmetrical and lateral halves united mesially by a suture, the line of which may be seen on the palatal surface of the bone, though the two halves obviously become fused together at a comparatively early period of life. This dumb-bell-shaped bone is situated in the hinder part of a fibrous membrane, which is attached behind to the anterior free border of the palate plate of each superior maxilla, on each side to the juner border of the intermaxilla, and in front it fills up the interval between the recurved tips of the intermaxillæ. This membrane, therefore, prolongs the palate forwards to the tip of the beak. The edge of the dumb-bell bone is surrounded by the membrane, and is attached by it to the anterior free border of the palate plate of the superior maxilla.

The upper surface of the dumb-bell bone lies immediately subjacent to the anterior somewhat expanded end of the vomer, which is fused with it along its mesial line.

Opening on the surface of the palate immediately superficial to the concave lateral border of the dumb-bell bone, is the incisive foramen, which lies therefore in the interval between it, the superior maxilla and the intermaxilla forming the anterior end of the beak. A bristle readily entered the incisive foramen, and could without difficulty be passed backwards for some distance. It did not, however, lie in the cavity of the nose, but in a distinct canal situated in relation to the septum nasi. The canal with its walls formed the organ of Jacobson in this animal. When the nasal chamber was opened into a ridge was seen, which projected transversely from the side of the nasal septum, nearly half-way across the nasal chamber, and the canal of Jacobson was contained in this ridge. The wall of this canal consists partly of cartilage and partly of membrane continuous with the mucous membrane covering the nasal septum.

The cartilage formed a curved plate on the upper and outer wall of the canal, but below it was apparently deficient, as the outline of the bristle within it could be distinctly seen beneath

the mucous membrane. In its relation, therefore, to the incisive foramen, the dumb-bell-shaped bone corresponded with that portion of the palate plate of the intermaxillary in other Mammalia which lies between the incisive foramen and the mesial palatal suture. It would further seem that in *Ornithorhynchus* the ossification of the fibrous membrane which forms the septum between the nose and the mouth is defective, so that the more anterior part of the roof of the mouth does not undergo an ossific change, but remains as a fibrous membrane, except in the limited area where the dumb-bell-shaped bone is produced.

Some anatomists have, however, expressed a different opinion on the homology of the dumb-bell-shaped bone. In his *Comparative Anatomy of Vertebrates*, Sir Richard Owen¹ speaks of it as a small prenasal ossicle, and does not, as in his previous article "Monotremata," associate it with the palatine process of the intermaxilla. Professor Flower regards it² as situated in the triangular interval between the diverging premaxillæ, placed in, or in front of, the anterior extremity of the mesethmoid cartilage, and apparently corresponding to the so-called prenasal of the pig.

I felt it to be necessary, therefore, to dissect the naso-palatine region of the pig in order to compare it with the dissection of the *Ornithorhynchus* just described, and I shall now give a short account of the position and relations of the prenasal bone in this animal. The prenasal of the pig is articulated with a definite area on the nasal surface of the alveolar part of the two intermaxillary bones, which bones articulate with each other anteriorly and mesially. It curves upwards and forwards in front of the anterior end of the vomer and the anterior end of the septal cartilage, to the latter of which it is intimately connected. By its upper end it is connected with the cartilage which forms the roof of the anterior nares. It has no relation whatever either to the palatal aspect of the mouth or to the incisive canal. This canal in the pig opens in the usual way on the roof of the mouth immediately behind the upper incisor

¹ Vol. ii, p. 322, 1866.

² *Osteology of Mammalia*, p. 219, 2nd ed., 1876.

teeth. Its opening, when the soft parts are in place, is very small, and partially concealed by a projecting fold of the mucous membrane. In the macerated skull it is seen to be bounded externally and anteriorly by the thick alveolar border of the intermaxilla, posteriorly by the anterior border of the palate plate of the superior maxilla, and internally by a comparatively thin plate of bone which the intermaxilla sends back from the region of the central incisor tooth to join the palatal plate of the superior maxilla, and which bounds the mesial palatal suture. This plate of the intermaxilla and not the prenasal bone corresponds in position to the dumb-bell-shaped bone of *Ornithorhynchus*.

The prenasal bone of the pig therefore has a very different position and relation from the dumb-bell-shaped bone of *Ornithorhynchus*. It lies in front of the vomer and mesethmoid septal cartilage; it assists in bounding the anterior nares; it lies on a plane dorsad to the premaxilla, and has no relation either to the palate or naso-palatine canal. The dumb-bell-shaped bone, on the other hand, is inferior to the vomer, and fused with its inferior border; it has no relation to the anterior nares; it enters into the constitution of the hard palate, and it forms the inner boundary of the entrance into the naso-palatine canal. In its position and relations it corresponds with that part of the intermaxilla which lies between the incisive canal and the mesial palatal suture. All these facts therefore support the opinion advanced so many years ago by Rudolphi, by J. F. Meckel, and by Owen, in his article "Monotremata," and to which attention has anew been directed by Albrecht, viz., that in *Ornithorhynchus* the intermaxilla is divided into two bones by a considerable interval,—an outer part which enters into the formation of the beak, and an inner part which lies on the palatal aspect of the jaw, in front of palatal plate of the superior maxilla, and in relation to the mesial line of the palate.

THE INFRA-ORBITAL SUTURE. By Professor W. TURNER,
M.B., F.R.S.

IN my Report on the Human Crania, collected during the voyage of H.M.S. Challenger,¹ I described, and in two specimens figured, the presence of an infra-orbital suture in adult Bush, Australian, Admiralty Island, Sandwich Island, Chatham Island, and New Zealand crania. This suture was usually denticulated. It was visible on the face, and extended from the infra-orbital foramen, through the inferior border of the orbit, and passed backwards through the roof of the infra-orbital canal; it was situated immediately internal to the malo-maxillary suture.

My observations on the crania of the different races of men have shown me that this suture is not limited to the crania of exotic and uncivilised races, but is also sometimes met with in the skulls of adult Europeans. In addition to its occasional presence in the adult, it is almost invariably found in a more or less perfect condition in foetal and young European crania, and is therefore a normal arrangement in the development of the roof of the infra-orbital foramen and canal. I have now before me twenty-eight young European skulls or upper jaws, not specially selected with reference to this point, and ranging in age from the edentulous foetus to the child's skull with all the milk teeth erupted, and with the first permanent molar in place. In all of these specimens this suture was present.

It varied somewhat in its direction in different specimens. In some it passed vertically upwards from the infra-orbital foramen through the lower border of the orbit into the roof of the canal,² and then along the roof to its posterior border, and in eight of these it crossed the anterior end of the malo-maxillary suture. In several of the jaws it inclined upwards and somewhat inwards along the side of the base of the ascending process of the superior maxilla to the inner end of the lower border of the orbit, so that a much longer extent of this suture was visible on the

¹ *Zoology, Challenger Expedition*, part xxix., 1884.

² A figure of the superior maxilla of a five-months' foetus, showing this form of the suture, is given by R. Quain in *Quain's Anatomy*.

facial aspect of the superior maxilla than in the cases where its direction was vertical.¹ In some of these specimens, in addition to being prolonged backwards into the roof of the infra-orbital canal, the suture gave off a branch, which reached the border of the lachrymal groove in the superior maxilla. It was then prolonged for a short distance down the anterior wall of the groove in which the lachrymo-nasal duct was lodged, and in three instances was seen to reach the anterior border of the entrance into the antrum. There would thus appear to be an area of ossification in the inner half of the orbital plate of the superior maxilla, distinctly demarcated from the outer half of the orbital plate and from the ascending process of the superior maxilla. This area articulates by its inner border with the os planum of the ethmoid, and may appropriately be designated the ethmoidal division of the orbital surface of the superior maxilla; whilst the part of the same surface which lies external to the infra-orbital suture may, from its articulation with the malar bone, be termed the malar division of the orbital surface of the superior maxilla.

The constancy of this suture in the young skull shows that the roof of the infra-orbital foramen and canal is not closed in by the ossific process so early as the floor. In the ossification therefore of the membrane out of which the superior maxilla is produced, the formation of bone takes place earlier and more rapidly in relation to the under surface and sides of the infra-orbital vessels and nerves than to their upper aspect. This is in accordance with what has been seen in the early development of the superior maxilla. Mr G. W. Callender states² that in a foetus 9 inches long, the infra-orbital fissure is still open in its entire length, and that deposits of bone arise on either side of the fissure and deepen it. Henle describes³ a trace of this suture as not unfrequently seen on the facial aspect of the jaw in the first year of life, which persists for a longer time on the orbital surface of the bone.

The presence of an infra-orbital suture in an adult skull,

¹ This suture is not to be confounded with the suture longitudinalis imperfecta (Weber), a figure of which is given by Henle in his *Knochenlehre*, which ascends in relation to the facial aspect of the upper part of the ascending process anterior to the groove for the lachrymal sac.

² *Phil. Trans. Roy. Soc.*, London, 1868.

³ *Handbuch der Knochenlehre des Menschen*, 1855.

whether European or otherwise, is therefore the persistent evidence of a fissure normally present in an early stage of development, but which becomes obliterated in the majority of crania in the adult condition, though it is present in a larger proportion of adult crania than has hitherto been recognised by anatomists.

I have also made some observations on the infra-orbital region in the skulls of the anthropoid apes in the Anatomical Museum of the University of Edinburgh. The infra-orbital canal was in them more widely patent than in the human orbit, and as a rule it remained as an open groove almost up to the lower border of the orbit. No trace of the infra-orbital suture was seen in the crania of the adult Gorilla, Chimpanzee, or Orang. Similarly in the crania of three young orangs, two of which possessed the milk dentition together with the first permanent molars, and the third had, along with the permanent incisors, anterior molars, and bicusps, the milk canines, there was no trace of this suture. In a young gorilla, in which the permanent canines were not erupted, there was no trace of the suture in the roof of the canal or in the interval between the infra-orbital foramen and the lower border of the orbit. But the remains of a suture extended from the groove for the lachrymo-nasal duct and lachrymal sac, for a little more than a centimetre, on the facial aspect of the superior maxilla by the side of the ascending process in the direction of the infra-orbital foramen, though not reaching it. This suture obviously corresponded with the upper end of one of the varieties of the infra-orbital suture which I have described on page 218, and had at an earlier stage of development undoubtedly been prolonged into the infra-orbital foramen and the roof of the infra-orbital canal.

ADDITIONAL NOTE ON THE OVIDUCTS OF THE
GREENLAND SHARK (*Læmargus borealis*). By Pro-
fessor W. TURNER, M.B., F.R.S.

IN July 1878, I published in this *Journal*¹ a note on the oviducts of the Greenland shark. A few days ago I had the opportunity, through the courtesy of my colleague, Dr Ewart, Professor of Natural History, of dissecting a very fine female specimen of this Elasmobranch. It was captured about the middle of December off Montrose, and was forwarded by the Messrs Johnston of that town to Dr Ewart.

The shark measured 11 feet 6 inches from the end of the snout to the tip of the upper lobe of the tail. When the abdominal cavity was opened into, and when the liver and alimentary canal were carefully removed, a pair of ovaries, each about 15 inches long, was seen to be attached to the dorsal wall of the abdominal cavity. The ovaries resembled in appearance those in the specimen of this shark which I described in my first paper on this fish;² but the ova had only the size of small granules.

On the outer side of each ovary a well-marked oviduct was at once seen, extending in the longitudinal direction. Each duct was $\frac{3}{8}$ of an inch in external diameter, and readily allowed a piece of india-rubber tubing to be passed along it. The ducts contained inspissated mucus. They were considerably wider than in the female—about 7 feet long—described in 1878, in which they were about the size of a goose-quill; and the ovaries were also of greater magnitude. Anteriorly the ducts converged in close relation to the anterior end of the liver, and became enveloped in a common fold of peritoneum. They then ran side by side for about an inch, being separated only by a thin septum, when they opened close together into the base of a spathe-like canal. The spathe rapidly opened out in front of the mouths of the ducts, became shallow and attenuated, and terminated in a free pointed end. It was $13\frac{1}{2}$ inches in length from the openings of the ducts; and, as it had some mobility, it is

¹ *Jour. of Anat. and Phys.*, vol. xii. p. 604.

² *Ibid.*, vol. vii. p. 241, 1873.

possible that its shallow canal could, during shedding of the ova, be brought into contact with a portion of the surface of each ovary, and that in this way the ova could be guided into the oviducts. But, as it is very doubtful if the entire surface of each ovary could be embraced by the spathe-like canal, a proportion of the ova would probably be shed into the peritoneal cavity, and be evacuated through the abdominal pores.

The cloaca had an arrangement of ducts and openings similar to what I found in the specimen described in 1878, so that I do not require to repeat the description.

When the abdominal cavity was cut into, the stomach was seen to be distended with food; and, as its contents illustrate in a very striking manner the voracity and destructive power of these sharks, it may be as well to state what the stomach contained: a cod-fish, 38 inches long; a female salmon, 29 inches long; a male salmon, 36 inches long; nine haddocks, a small skate, the shell of a large buccinum; the carcass, without the head, of a small cetacean, perhaps a porpoise; a number of masses of blubber and flesh, which, from the thickness of the blubber, had belonged to a much larger cetacean than a porpoise, but as the skull and other bones were absent I could not determine the species, so that it is possible that they may have been bitten out of the carcass of a large whale. No animal living in the sea seems, therefore, to come amiss to this shark, but it would appear to be especially enamoured of the fish used by man as food.

Dr Günther states¹ that this shark rarely strays to the latitudes of Great Britain. But this is an error, for the Greenland shark is one of the commonest of the large sharks frequenting the Scottish seas. Every year one or more is taken by the fishermen, and the mouths of the estuaries of the Forth and the Tay are infested by them. I have myself dissected eight specimens, and I have notes of the capture of several others, so that an enormous quantity of edible fish must year by year be destroyed by these creatures.

¹ *Introduction to the Study of Fishes*, 1880.

Anatomical Notices.

NOTES ON A DISSECTION OF AN EXCISED ELBOW. By R. T. SUTHERLAND, M.B., *Demonstrator of Anatomy, University of Edinburgh.*

THE elbow region of the left superior extremity of an adult male, about 50 years old, was seen to be contracted and marked with cicatrices, the limb being well developed both above and below.

The longest of the cicatrices measured $4\frac{1}{2}$ inches, and passed down on the inner aspect, but close to the middle line posteriorly, and extended about $1\frac{1}{2}$ inch along the humerus. Another cicatrix on the outer aspect of the elbow, and $1\frac{1}{2}$ inch long, lay parallel with the large one, and there were numerous small cicatrices both anteriorly and posteriorly; most of them were closely adherent to the bone, and caused depressions on the surface. The union between the bones was of the character of a flail joint, and the fore-arm could be flexed directly back to a right angle; the limb had been useful, as both fore-arm and hand were well developed. Radius rotated on the ulna about 90° ; thus, when the upper end of the ulna was fixed, the hand could be made to pass from pronation to between supination and pronation.

The lower end of the humerus presented no trace of either internal or external condyles, but was somewhat expanded laterally and curved forwards, the curvature being best marked on the anterior aspect, owing to a tubercle which presented itself towards the external border of the lower end, and projected forwards and curved inwards, resembling a flattened and enlarged styloid process of the ulna. A small tubercle lay towards the posterior border and caused a small fossa on the lower end. The rest of the surface was slightly tuberculated, but on the whole fairly regular.

The upper extremity of the ulna and radius lay at the same level, and there was a slight projection on the posterior upper aspect of the ulna. The head of the radius could be felt rotating on that of the ulna, but had a relation somewhat anterior to it. On reflecting the skin the bands of cicatricial tissue were seen to bind it closely to the bone.

Of the superficial parts only a small branch of the musculo-cutaneous nerve, which ended in a cicatrix, was cut.

The deep fascia was noticed to be much denser than in the normal condition, being specially thickened and blended with the muscles in the region of the elbow, but not as a rule strongly connected to the cicatricial bands, which could be easily defined.

Muscles.—The biceps had a distinct tendinous slip to the fascia

externally over the supinator radii longus; that to the fascia over the pronator radii teres was much thickened; the chief tendon was attached to the upper and inner end of the radius, but gave off a strong slip to a cicatricial band passing between it and the supinator radii longus.

The brachialis anticus had not its usual extensive attachment to the humerus, and the lower end presented a rather fascial appearance and was more or less blended with the surrounding tissue, but the greater part of the fibres could be traced down to attachment on the anterior aspect of the end of ulna and radius. The triceps was intersected in the mesial plane by the longitudinal posterior incision, which divided it into inner and outer masses of fibrous tissue, which was inserted into the fascia on the posterior aspect of the fore-arm, but chiefly into a mass of tissue which afforded origin internally and externally to those muscles which arise by common tendons from the internal and external condyles of a normal humerus. Some fibres blended with the cicatrices; a few were attached to a process on the upper end of the ulna somewhat resembling the olecranon process.

The pronator radii teres—rather embedded in the surrounding muscles—had no direct origin from humerus, but had a special slip from the tendon of the brachialis anticus and anterior process of the ulna superiorly.

The pronator radii teres, flexor carpi radialis, palmaris longus, and flexor sublimis digitorum had common origins from the mass of fibro-tendinous tissue, into which the inner half of the triceps was inserted. This mass extended between the humerus, radius, and ulna.

The supinator radii longus arose from the external border of humerus for $2\frac{1}{2}$ inches, from intermuscular septum, and by a strong slip of fibro-tendinous tissue from the radius below the tubercle.

As the pronator radii teres and the flexors had a common origin from the inner half of the triceps tendon, so the supinators and extensors had a common origin from the outer half of its tendon, and also from the upper end of the radius.

The anconeus muscle was altogether absent. The supinator radii brevis was represented by a few but distinct fibres arising from the ulna, on the outer border of its upper end. It was inserted into the radius for 2 inches above the origin of the extensor ossis metacarpi pollicis between it and the pronator radii teres, and also to the bone above and behind, up to 1 inch from the upper end.

The arteries presented no peculiarity. All the named branches were found. There was in this case a large median artery.

The Nerves.—The median lay internal to the brachial artery, and was separated from the ulnar by the slip of origin of the pronator radii teres from the ulna.

The ulnar, uncut, passed through the inner mass of fibro-tendinous tissue, to which its coverings were closely adherent.

The musculo-spiral lay between the brachialis anticus and supinator longus, passed through origin of latter from the humerus into the

extensor carpi radialis longior, in which it terminated by bifurcating into radial and posterior interosseous nerves.

The brachialis anticus and triceps were then divided transversely two inches above the lower end of the humerus, and the ends reflected upwards and downwards. In the case of the latter the fibro-tendinous masses were not cut.

A small bursa was found between the triceps and the outer corner of the humerus. No synovial membrane found in connection with the end of the humerus, the periosteum of which was thickened and loosely attached to the bone, being slightly roughened and porous looking.

A dense band of tissue was found passing from the anterior styloid-like process of the humerus to the upper end of the radius.

The fibrous tissue between the origin of the extensor minimi digiti and the extensor carpi ulnaris was dissected off, when the radius was exposed. This dense fibrous tissue was strongly adherent to that bone, and it was also bound to the ulna strongly by fibrous tissue, which, however, allowed a certain range of movement for rotation, and a sliding movement of $\frac{1}{2}$ -inch up and down also antero-posteriorly.

The upper end of the radius was curved slightly forwards and outwards, with a small process projecting forward on its anterior border, and this, with a tubercle on the posterior border, caused a depression, which was surrounded by adherent fibrous tissue between it and the humerus.

The tubercle of the radius lay $\frac{1}{2}$ -inch from the upper end.

The ulna had a subcutaneous surface, and curved well forwards, so that there was an anterior projecting lip like a very small olecranon.

The upper end of the radius and ulna lay in the same transverse plane.

[I may here call attention to another case of excised elbow dissected some years ago in the Practical Anatomy Rooms of the University of Edinburgh by one of my then assistants, Mr G. J. Malcolm Smith, M.B., and described by him in this *Journal*, May 1874.—W. T.]

NOTES ON A DISSECTION OF AN OLD UNUNITED FRACTURE OF THE LEFT PATELLA. By R. T. SUTHERLAND, M.B., *Demonstrator of Anatomy, University of Edinburgh.*

THE subject of this injury was a spare female, whose left thigh appeared thinner than the right, and the separated ends of the patella could be felt $2\frac{1}{2}$ inches apart, the upper fragment being more bulky than the lower, which was 1 inch distant from the tubercle of the tibia. On the right side the lower end of the sound patella was $2\frac{1}{2}$ inches

distant from the tubercle of the tibia. On removing the skin from the left knee the quadriceps extensor had the appearance of being less developed, and the rectus femoris was $1\frac{1}{2}$ inch shorter than on the right side. The patellar bursa of the right side was normal, but on the left side it was represented by a small sac, about $\frac{3}{4}$ inch diameter, lying on the lower fragment and the ligamentum patellæ. On the left side the deep fascia was stronger than usual, and the fibres forming the retinacula were better marked on the outer side than on the inner, and the bands on the two sides were connected by fibres passing transversely along the lower border of the upper fragment of the patella, and superficial to the broad strong band which connected the two fragments, and to which the synovial membrane, considerably thickened, was adherent. A small nodule of bone lay in this band $\frac{1}{2}$ inch above the middle of the lower fragment. A dense band passed down from either side of the upper fragment; the inner one, the weaker, derived fibres from the tendon of the quadriceps extensor, and was attached to the inner condyle of the femur anterior to the tubercle of the adductor magnus. It measured 3 inches long. The outer band passed downwards and slightly backwards, and, blending with the ilio-tibial band and tendinous fibres from the vastus externus, was attached to the external tuberosity of the tibia, and measured $4\frac{1}{4}$ inches long.

Pulling on the quadriceps extensor slightly extended the knee-joint by means of the two lateral bands, which were made more tense than the central.

The external lateral ligament of the left knee was more connected to surrounding tissue than that of the right. The synovial bursa between the ligamentum patellæ and tibia was more extensive on the right than left side. The synovial membrane of the right knee extended $\frac{1}{2}$ inch upwards above the articular cartilage on the anterior surface of the femur, which was smooth, while in the left knee it was thicker and extended 2 inches and was not smooth, being thrown into ridges and bands, which were in most cases fringed and ragged. Ligamentum alæ mucosæ frayed and ragged in left knee, and not strong as in right. Left knee, the upper fragment of patella was about $\frac{3}{4}$ more bulky than the lower, but the same in length and greatest breadth. The articular surface was comparatively smooth, but the cartilage was much wasted. The lower fragment was very irregular, pointed inferiorly, and the articular surface had lost its cartilage, and was coated with frayed-looking synovial membrane. The fracture appeared to have occurred along a transverse ridge between the upper and lower facets.

NOTES FROM THE DISSECTION OF A CHINAMAN. By
T. P. ANDERSON STUART, M.D. Edin., *Professor of Anatomy
and Physiology in the University, Sydney.*

THE dissection was made in the practical anatomy rooms of the University of Sydney. The abnormalities were almost solely in the muscular system and by way of excess.

M. Retrahens Aurem.—Superficial part well developed from fascia and middle third of inferior curved line of occipital bone.

Rectus capitis posticus major.—A pair on each side arising from the normal origin, coursing side by side and touching each other. The inner border of the inner one reached to about $\frac{1}{2}$ inch from the middle line of the body, while the outer border of the outer muscle extended as far as the outer end of the inferior curved line of the occipital bone. They entirely hid from view the recti capitis postici minores.

Rectus capitis posticus minor.—Represented on each side by three separate muscles, all arising from the neural arch of the atlas and adjacent deep part of the ligamentum nuchæ, and inserted into the occipital bone into and below the inferior curved line. The external muscle was inserted just below the inferior curved line, was entirely hidden by the outer piece of the rectus major, and extended inwards as far as $1\frac{1}{4}$ inch from the middle line. The insertion of the middle muscle extended from the former almost to the middle line. The internal muscle arose partly from the ligamentum nuchæ as high as the third cervical vertebra, had a fleshy belly $\frac{1}{2}$ inch in diameter when made cylindrical, ran alongside the ligamentum nuchæ to be inserted close to the middle line. The muscles as a whole were more strongly developed on the left side. On the right side the inner pieces were not quite separate, and but a few fibres came from the ligamentum nuchæ.

Omo-hyoid.—Posterior belly replaced by a membranous tendon.

Digastric.—A slip about one-third the usual size of the anterior belly crossed from the right to join the left anterior belly. The interval remaining between the anterior bellies was filled up by a fibrous membrane continuous with the sheath of the muscle, and with the fascia binding the median tendon to the hyoid bone.

Scalenus medius on both sides got two additional slips of origin from the serratus magnus.

Slender tendons, of the thickness of a darning needle, sprang, one from the flexor longis pollicis to be attached to the deep surface of the anterior annular ligament, one from the flexor profundus digitorum inserted into the synovial sheath beneath the anterior annular ligament, and one from the extensor ossis metacarpi pollicis to be part origin of the abductor pollicis. The last-named muscle had two tendons separate throughout. The supinator radii longus also had a split tendon through which the radial nerve passed. The ulnar origins of the pronator teres and of the flexor longus pollicis were very large.

Semimembranosus, two inches below its origin, gives off a tendinous slip, soon becoming muscular and joining the vertical fibres of the adductor magnus.

Lumbricales pedis.—Left side, second and third wanting; on right side third only wanting.

External saphenous nerve on both sides supplies dorsal aspect of $2\frac{1}{2}$ outer toes, and communicates with the musculo-cutaneous.

Sciatic artery greatly reduced in size, supplemented by a large branch of the gluteal, which passes backwards over the pyriformis and gives off the coccygeal and anastomotic branches of the sciatic.

NOTE ON THE PERITONEUM OF THE SEAL. By R. J. ANDERSON, M.A., M.D., *Professor of Natural History, Queen's College, Galway.*

THE fleshy stomach is suspended to the diaphragm by the gastrophrenic ligament, and to the liver by the gastrohepatic omentum. The same viscus is connected to the spleen by the gastrosplenic. The small sac touches the spleen for the extent of 4 inches, and communicates with the great peritoneal sac in the ordinary way. The great omentum forms a pendulous fold, and is attached by one end to the stomach, and by the other to the posterior abdominal parietes. Close to the latter the pancreas is enclosed between its layers.

The duodenum is about a foot long, and forms a curve with its convexity towards the right side, and is attached to the posterior abdominal wall by a mesentery 5 inches in length, and the latter receives the right end of the pancreas between its layers. The large intestine begins close to the middle line between the two ends of the duodenum, is attached in all its extent by a mesentery, and terminates in the rectum. The mesentery that fixes all the small intestines to the posterior abdominal wall, is attached between the place of origin of the large intestine and the point of termination of the duodenum. The breadth of the mesentery is 6 inches. The cæcum has a slight bend to the right, the rest of the large intestine is median.

The small sac of the peritoneum may be traced to the posterior surface of the stomach, thence proceeding upwards to the liver and diaphragm, then it turns round to touch the posterior abdominal wall and to cover the pancreas, and then to form the lining of the omental sac. Traced to the left it covers the vessels going to the spleen, and touches that viscus for the distance already indicated, and becoming continuous with the small sac through the foramen of Winslow.

The freedom of the great omentum from the colon, and the continuation of the pancreas from the omental into the duodenal mesenteries, is so very marked that I am disposed to view the

arrangement as evidence in favour of the view I advanced some time ago,¹ viz., that the small sac is really a mechanical result of the friction of the stomach and liver on the posterior abdominal parietes. It is well known that the liver develops to the right, and the pancreas to the left. The hepatic and coronary arteries keep to the right, the splenic and a portion of the hepatic go to the left. The foramen of Winslow, absent in some cases, can be readily accounted for by the growth backwards of the liver. Speaking generally, the coronary artery supplies the first part of the gastro-duodenal portion of the intestinal tract, the splenic artery the second, and the hepatic the third.

NOTE ON A PECULIAR SHAPED KIDNEY. By J. CUNNING-
INGHAM RUSSEL, M.D., *The County Asylum, Lancaster.*

THIS peculiar shaped kidney was found on making the *post-mortem* examination of a man, aged 55 years.

On the right side there was no trace of any kidney. The suprarenal capsule was present as usual.

On the left side there was a large kidney, 8 inches long, $3\frac{1}{2}$ inches broad at both its upper and lower ends, and $2\frac{1}{2}$ inches broad in the middle. The thickness did not differ from that of an ordinary kidney. The upper end lay in the usual position of the left kidney. The body of the organ lay with slight obliquity inwards, so that the lower end rested on the bodies of the lumbar vertebrae, reaching about the middle line, and to $\frac{3}{4}$ inch from the sacral promontory. There were two hiluses, one in the upper and one in the lower part, separated by a portion in the middle, without a hilus, about 1 inch long. A renal artery in the usual situation went to the upper hilus; a smaller artery, springing from the front of the aorta below the inferior mesenteric, went to the lower hilus; a branch from it penetrated into the middle part of the kidney on its anterior surface. There was one vein receiving branches from both hiluses. There were two ureters, the upper taking the usual course of the left ureter. The lower and smaller crossed the middle line just above the sacral promontory, and went to the right side of the bladder, resembling in its lower course the normal right ureter.

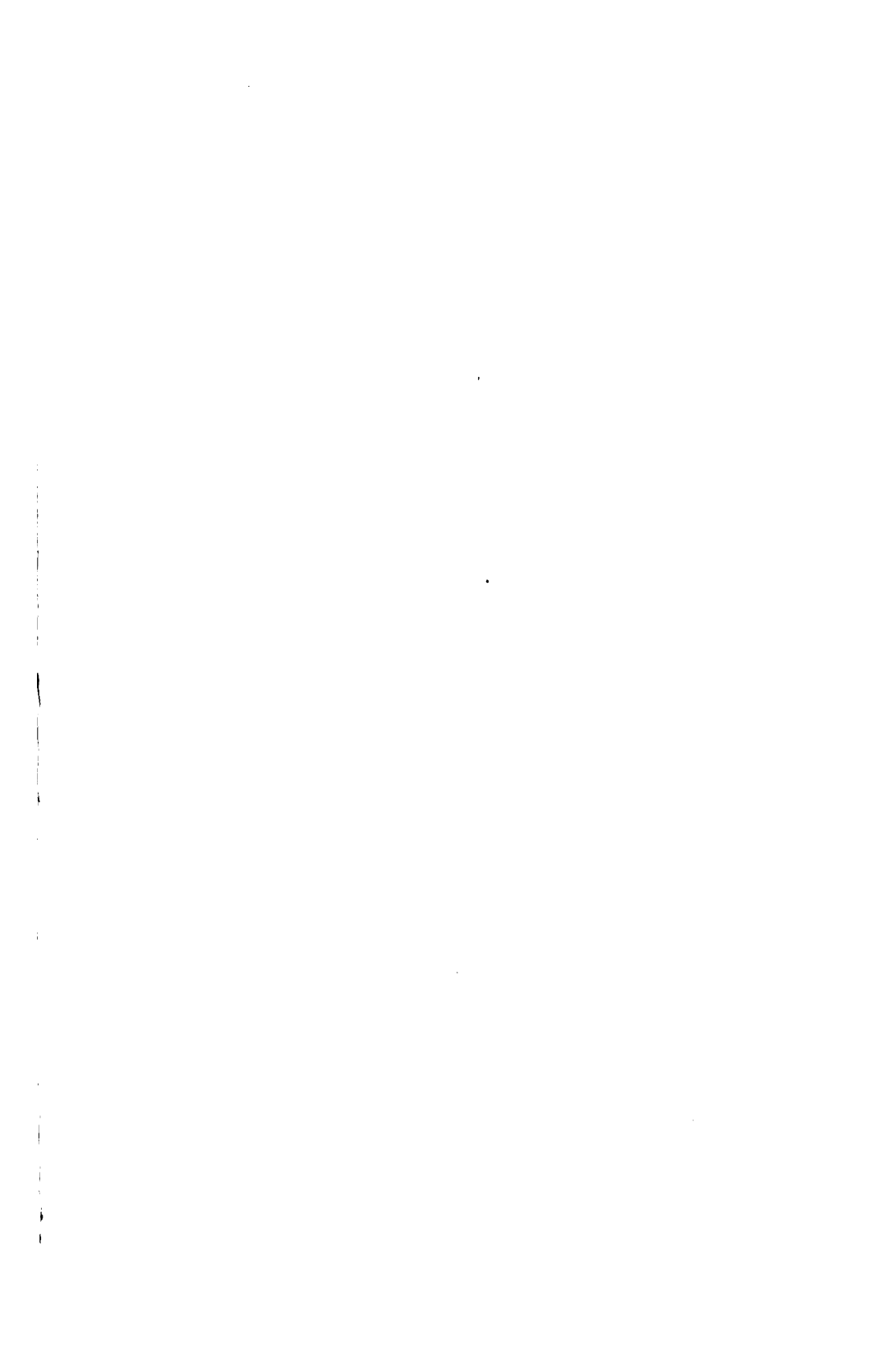
The section through the organ shows an arrangement like that of two kidneys joined by their ends, there being two separate pelves.

¹ *Dublin Journal of Medical Science*, Sept. 1883.

ADDITIONAL NOTE ON THE DELINEATION OF SKULLS
BY COMPOSITE PHOTOGRAPHY. By ARTHUR THOMSON,
M.B., *Senior Demonstrator of Anatomy in the University of Edinburgh.*

I HAVE learned, since the publication of my paper on this subject in the last number of this *Journal*, that Mr Francis Galton, F.R.S., had three years previously drawn the attention of the Anthropological Department of the British Association to the application of composite portraiture to anthropological purposes, and had exhibited a composite photograph of eight skulls of Andaman islanders, which he had mounted under the instructions of Professor Flower. The separate portraits were combined into a single composite by a new instrument invented by Mr Galton, and described by him in the *Photographic Journal* of June 1881. It is also worthy of note that Dr J. S. Billings of Washington has been engaged in a similar line of investigation, and contributed, in April last, a preliminary paper on the subject, with photographs, at a meeting of the National Academy of Sciences.

An account of Mr Galton's communication will be found in the report of the British Association meeting held at York, 1881, p. 690.



EXPLANATION OF PLATE VI.A

In illustration of the Paper on "Abnormal Disposition of the Colon,"
By R. BRUCE YOUNG, M.A., M.B., *Demonstrator of Anatomy,*
Glasgow University. Page 98.

Fig. 1. View of the abdominal viscera, showing the abnormal disposition. *a*, Ascending portion of the colon; *b*, descending portion of the colon; *c*, coils of small intestine; *d*, duodenum where it curved round gall-bladder; *e*, membrane (probably adherent great omentum) shutting off the upper part of the abdominal cavity; *f*, band of adhesion passing from duodenum to mesentery; *g*, the two peritoneal projections on the ascending portion of colon; *h*, liver; *i*, mesentery; *k*, sigmoid flexure.

Fig. 2. Stomach and intestines of a foetus ($1\frac{1}{2}$ inch long from vertex to coccyx) (see page 105). *a*, Pylorus and beginning of duodenal curve; *b*, upper end of jejunum; *c*, caecum; *d*, descending colon. The vermiform appendix is relatively very long.

Fig. 3. Diagram of development of alimentary canal, showing the primary loop with remains of umbilical vesicle attached and supplied by the superior mesenteric artery; the upper loop supplied by the coeliac axis, and the lower loop supplied by the inferior mesenteric artery. In the case described in the paper the caecum had been prevented from crossing over the upper limb of the primary loop.





FIG. 1.



Artotype.

FIG. 2.

J. G. Tunny.



FIG. 3.







Fig. 1.
Anteverted Uterus
(Monkey)

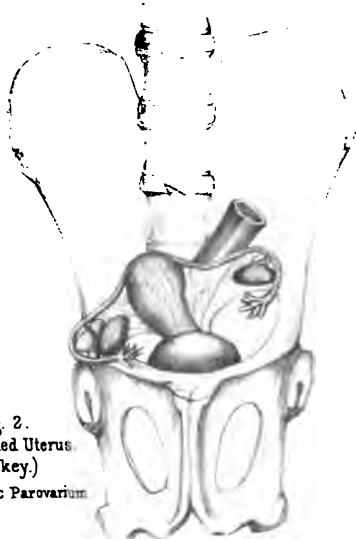


Fig. 2.
Retroverted Uterus
(Monkey)
Cystic Parovarium

12

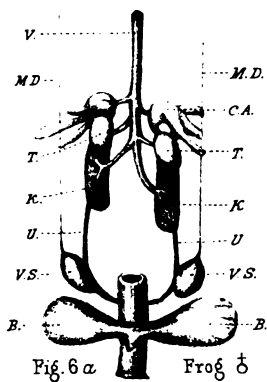
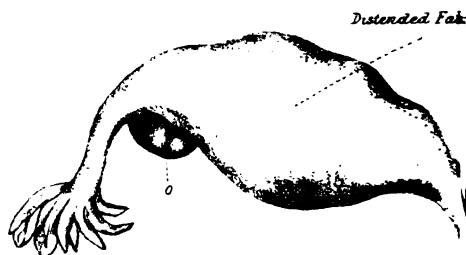


Fig. 6a Frog ♂



Fig. 9
(Homo.)



Distended Fallopian Tube

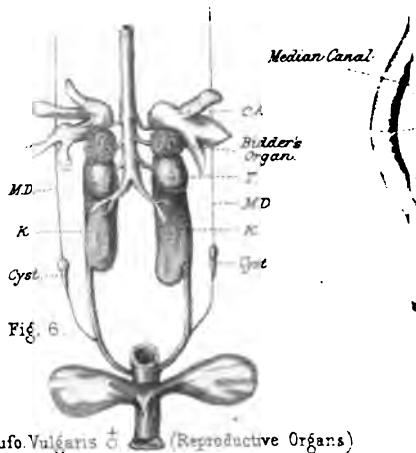


Fig. 6

Bufo Vulgaris ♂ (Reproductive Organs)



Fig. 3.
Lateral Flexion
(Monkey)

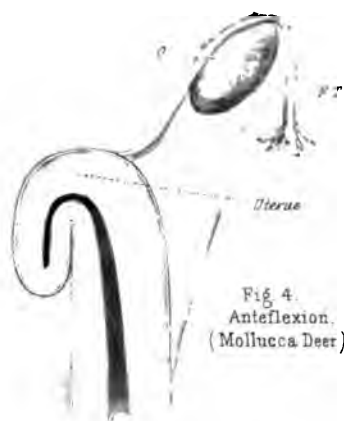


Fig 4.
Anteflexion.
(Mollucca Deer)



Fig. 5.
Uterus of Kangaroo.
Pyo-Salpinx.

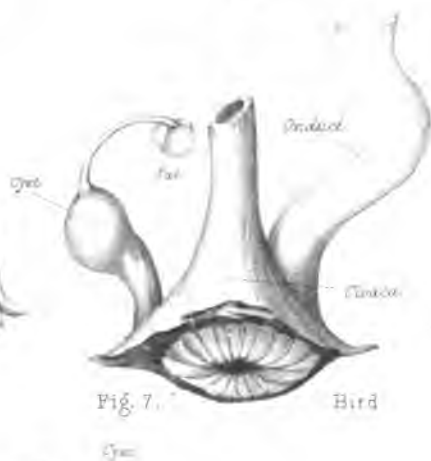


Fig. 7. Bird



Feb 8
(Mare)

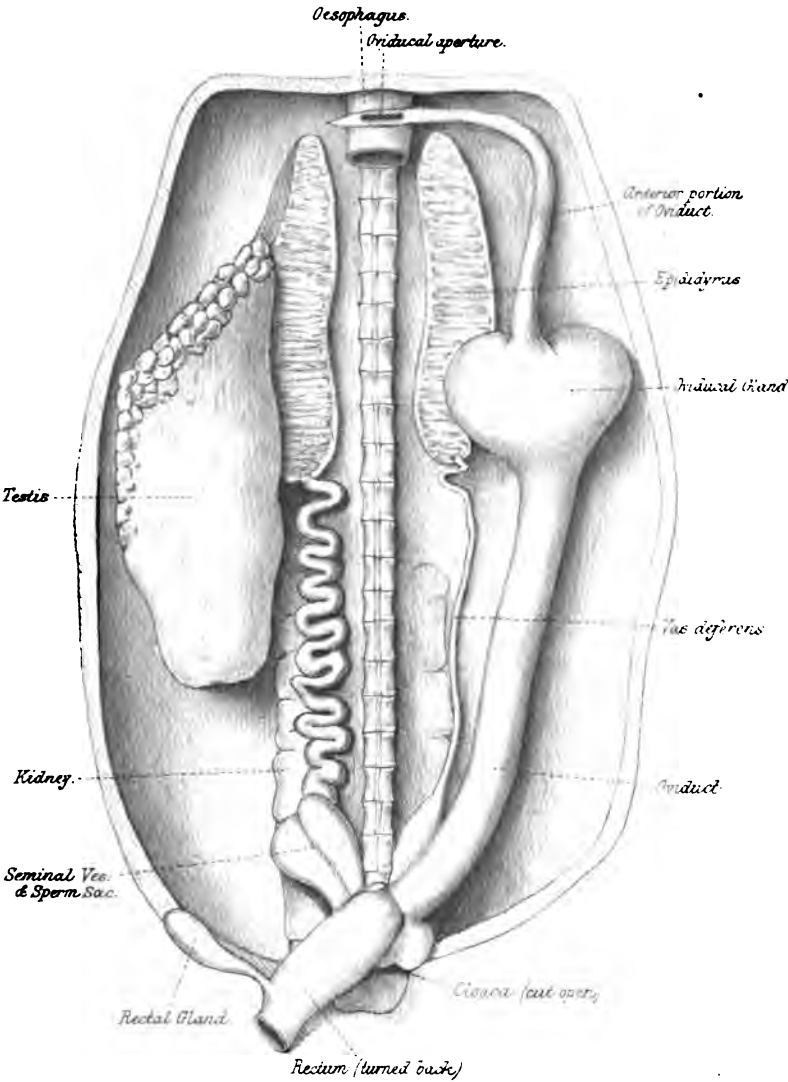


Fig. 1.

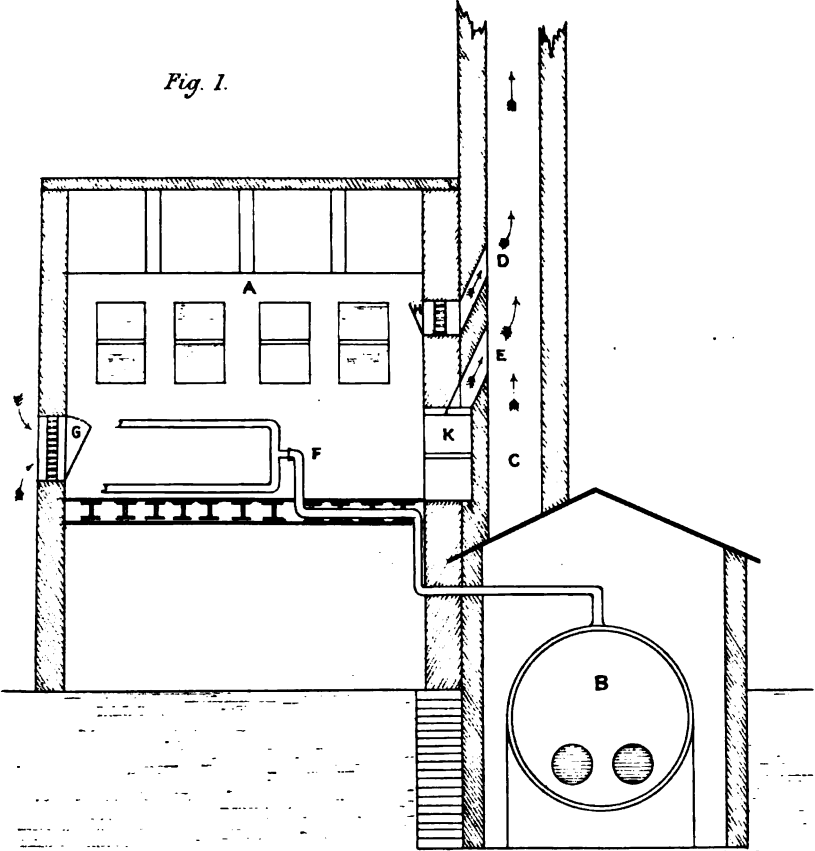
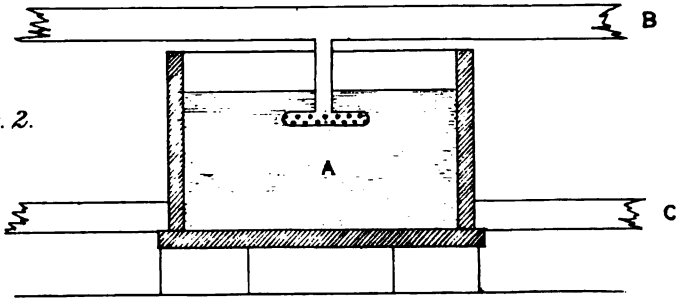


Fig. 2.



Journal of Anatomy and Physiology.

THE DEVELOPMENT OF THE BLOOD-CORPUSCLES
IN THE EMBRYO OF *PERCA FLUVIATILIS*. By
K. F. WENCKEBACH, *Med. Stud., Temporary Assistant at the
Zoological Laboratory, University of Utrecht.* (PLATE XI.)

WHEN, in April 1884, I had occasion to investigate certain points in the embryology of *Perca fluviatilis*, I was struck by the facility with which these embryos may be studied while alive, this being chiefly due to their small size, and especially to their extraordinary transparency. All the different organs are visible *in situ*, and in their whole extent, at least as long as the embryos are still enclosed in the capsule, at which period the radiating pigment cells only just commence to make their appearance.

The circulation of the blood could easily be followed in all its details, and I was more or less puzzled that the blood-corpuscles made their appearance rather suddenly. This led me to suppose that it ought not to be difficult, in this particular case, to determine their mode of origin.

Up to that particular stage of the development, in which pigment makes its first appearance in the eye, the heart may be seen to pulsate very distinctly, as may also be ascertained for the walls of the larger vessels; but it is not possible to decide upon the presence of any circulating fluid in these organs by the fact of any such fluid, if present, being absolutely colourless and deprived of any corpuscles, which might serve to render this circulation apparent.

At the time that the first blood-corpuscles are seen shooting through the vessels, the whole circulatory system is yet limited

(see Plate XI. fig. 1) to the heart with its double curvature, from which as yet only one pair of aortic arches takes its origin. The walls of the anterior arches are just commencing to make their appearance, but as yet no blood circulates through them. The two first arches unite dorsally into an aorta, which lies immediately under the notochord as far as the middle of the tail. At that point it bends downwards, and then again forwards, thus constituting a vein which K. E. von Baer has called the *vena caudalis inferior*. This is continued into the *vena vertebralis posterior sive cardinalis* (Rathke), which, after forming a small glomerulus in the pronephros, sends the blood into the *sinus venosus*, from which it flows back into the heart.

This *vena vertebralis* quite constantly shows a longitudinal dilatation, which is entirely filled with small spherical cells. I was immediately struck by the similarity in appearance between these cells and the solitary blood-corpuscles that may be noticed in this stage,—they were equal in size, and both can be shown to possess a spherical nucleus after treatment with acetic acid. They were, moreover, of the same pale colour, the blood-cells acquiring their light yellow tint only after they have circulated for a certain time.

I felt inclined to believe that this part of the *vena vertebralis* produced the blood-cells, and this view was very soon confirmed by the fact that I obtained several stages in which the rapidly-circulating blood-fluid which flows through this *vena*, even though it be chokefull with cells, succeeds in detaching and carrying away some of these cells. This detachment may affect either solitary cells or groups of cells, the latter breaking up and then continuing their course through the body as normal blood-corpuscles. I have repeatedly been able to observe the detaching process of these cells in quite normal embryos. It takes place rather rapidly; thus, in an embryo under observation, the number of blood-corpuscles was more than quintupled in twenty-five minutes. The detaching process may have been accelerated in the cases I experimented with, because I always removed the egg membrane, and thus enabled the embryo to move and to contract much more vividly. The animal under observation was always placed in a drop of water suspended to the under surface of a

cover-glass, thus obviating any pressure which might be exercised by the latter, and give rise to abnormal phenomena of development. At the same time, the use of high powers was possible.

I now wish to show that the phenomena of defective circulation ("mangelhafte Circulation") against which K. E. von Baer, and after him Reichert, have especially warned us, cannot have come into play in the cases under observation. Reichert, for example, tells us¹ (p. 26):—"I have already shown that in the first instance the phenomena which are the consequences of defective circulation of the blood have exercised a certain influence on the current opinions on the formative process in question."

He then describes this phenomenon, and concludes:²—"By an adhesion of the blood-corpuscles to the walls of the vessels, and by the formation of insular groups of blood-corpuscles, the corpuscula sanguinis are partly, nay even wholly, detracted from the circulation of blood."

That such is wholly out of the question in the cases above recorded can be easily demonstrated.

The detaching process of the cells is a *constant* phenomenon, but is *entirely* limited to the stage of development which has been figured, and which is characterised by the appearance of pigment in the eye.³ Before this stage I have never been able to observe any blood-corpuscle in the circulatory apparatus.

If, on the contrary, the detachment of cells from the central mass filling the vessel were to be ascribed, as Reichert will have it, to an incipient dissolution of a blood-clot, which had there been secondarily formed, it would certainly not be so constant, and at the same time so decidedly limited to one stage. Moreover, the cells before their detachment are wholly colourless,

¹ Reichert, *Studien d. Physiol. Instituts zu Breslau*, Beobachtungen über die ersten Blutgefäße und deren Bildung, sowie über die Bewegung des Blutes in denselben bei Fischembryonen.

² *Loc. cit.*, p. 27.

³ It was not possible to fix the exact age of these embryos to any definite number of days, as they were procured from ponds, and the exact date of the oviposition was thus unknown. Moreover, the temperature has a great influence on the rate of development of the embryos.

whereas the blood-corpuscles that have been already circulating for a certain time always have a yellow colour.

Finally, I found in embryos which had been specially prepared, and from which I obtained a continuous series of sections, that the circulating blood cells can be easily distinguished from those that are still adherent, by having a somewhat thicker layer of clear protoplasm around the nucleus, and at the same time by the more oval shape which very soon characterises them.

All this, in addition to the fact already alluded to, that the embryos could be observed under very normal circumstances, and that the pulsations of the heart were continued rapidly and rhythmically during a very considerable lapse of time, excludes the possibility of a confusion with phenomena that must find their explanation in a defective circulation in the sense of Reichert.

I have, moreover, had occasion to observe certain processes on the yolk-sac which simulated the formation of blood-corpuscles, but which were only the consequence of blood accumulation. During the formation of the blood-vessels on the yolk-sac, which appear to arise as lacunæ in the tissue, groups of cells may be noticed, from which solitary cells or a few adherent cells are gradually detached. In this case, however, it is already-formed blood-corpuscles which often are heaped up in the blind end or in a lateral branch of a vessel which is just being formed, and which shortly afterwards are again set into circulation when these circumstances come to change.

Transverse sections through embryos, which had been preserved in corrosive sublimate, and had been stained with picrocarmine, entirely confirmed the observations which I had made on the living specimens. From these it was apparent that the portion in question of the vena vertebralis is first a solid cord, which on further development gradually shows an increasing number of lacunæ (figs. ii. and iii., 1-7).

Reichert's conclusions, which I have not been able to verify in respect to the heart and the other vessels, appears to hold true for this portion of the vein when he says:¹—"Dass, wie für das Herz mit seinem Inhalte, so auch für die übrigen embryonalen Gefässe mit ihrem Blute an Ort und Stelle, wo sie liegen,

¹ *Loc. cit.*, page 32.

gemeinschaftliche Anlagen sich sondern, in welchen durch einen nachträglichen Sonderungsact die Axensubstanz oder centralen Masse zur Anlage für das zugehörige Blut, die periphere Rindenschicht für die Gefäßwandung bestimmt werden und respective sich darein verwandeln."

However true this deduction of Reichert's may ultimately be proved, it is to be noticed that he did not adduce any actual observations by himself in confirmation of it, and only concluded "von Gleichem auf Gleiches." In *Perca fluviatilis* the phenomenon is perhaps limited to the vena vertebralis, where, however, as we have seen, it is very evident. In the other vessels, although they were wholly formed and provided with distinct smooth surfaces, there was nevertheless not a single blood-corpuscle; this makes it improbable that here also blood-corpuscles might arise in addition to those that are formed in the vena vertebralis.

Anteriorly, the vena vertebralis often appears to be divided into two. Reichert believes this to be always the case. I am not prepared to express any definite opinion on this point. It might possibly be in some way connected with the formation of two glomeruli, a right one and a left one, in the pronephros.

I cannot make any definite statement as to the exact way in which this mass of cells makes its appearance in the mesoblast, the embryos being very small, and the yolk becoming so extremely hard in the preserving reagents, that it is extremely difficult to obtain series of satisfactory sections.

The conclusion to which I have thus arrived, and which, as far as I can make out, is new to science, can be formulated as follows:—

In *Perca fluviatilis* the blood-corpuscles arise as a solid mass of tissue, situated in the region where afterwards the vena vertebralis will be found. The central portion of this cylindrical mass of cells gradually loosens, the cells are carried away by the blood-fluid which has appeared in the meantime, acquire a yellow tint, and become the blood-corpuscles.

EXPLANATION OF PLATE XI.

Fig. 1. Embryo of *Perca fluviatilis*, in which pigment just commences to appear in the eye; *br.*, brain; *ol.*, olfactory pit; *o.*, eye; *aud.*, auditory vesicle with two otoliths; *s.c.*, spinal cord; *not.* notochord; *ao.*, aorta; *v.c.*, vena caudalis; *v.v.*, vena vertebralis posterior s. cardinalis; *ves.*, vesicle in which end the Wolffian ducts; *cl.*, cloaca; *g.*, gut; *glm.*, glomerulus of the pronephros; *y.s.*, yolk-sac; *o.d.*, oil drop; *s.v.*, sinus venosus; *h.*, heart; *pc.*, pericardium; *a.a.i.*, first aortic arch; *f.s.*, fold of the skin; *o'.f.*, first rudiment of the pectoral fin; *n.s.*, natural size.

Fig. 2. Transverse section through an embryo of *Perca fluviatilis*, slightly younger than fig. 1; *not.*, notochord; *ao.*, aorta; *c.m.*, cell mass, which fills the vena vertebralis throughout its whole extent; *m.p.*, muscle-plates; *W.d.*, Wolffian duct; *g.*, gut.

Fig. 3. (1, 2, 3, 4, 5, 6, 7) Series of succeeding transverse sections through an embryo of *Perca fluviatilis*, slightly older than fig. 1, to show how irregularly the cell-mass of the vena vertebralis is carried away by the rapidly-flowing blood; *not.*, notochord; *ao.*, aorta; *m.p.*, muscle-plates; *v.v.*, vena vertebralis; *W.d.*, Wolffian duct; *g.*, gut.

THE MOVEMENTS OF THE ULNA IN ROTATION OF
THE FORE-ARM. By JACOB HEIBERG, M.D., *Professor
of Anatomy in the University of Christiania, Norway.*

No doubt the relative movements of the radius and the ulna, as well in the elbow-joint as at the wrist, yield one of the most interesting, but at the same time one of the most difficult, points in arthrology. When I now have taken this question up, and published a pamphlet upon it (Jacob Heiberg, *Ueber die Drehungen der Hand*, Wien, 1884), as the result of more than one year's hard work in all my free-time, I must feel very flattered when a man of Professor Dwight's capacities takes up the discussion¹ and attracts still more attention on the question. It has caused me very much satisfaction that Professor Dwight, like Professor von Meyer in Zürich,² has repeated my experiments and found that my observations were correct; when Professor Dwight then adds that my "interpretation is wrong; that, though the ulna may move in rotation, it does not rotate," so I am able to admit without delay that I am of the same opinion, that the ulna does not rotate in the sense of Professor Dwight. When I have been misunderstood by Professor Dwight, and perhaps by many others, I suppose the cause lies therein, that the verb rotate has a much more restricted signification in English than it has in the German, Scandinavian, French, Italian, and other Roman languages which I may know. As far as I can understand, it only signifies a cylindrical motion around the object's own axis, like the movement of a rolling pin used in the houses when baking. Well, I never found and never had the intention to state that the ulna or the radius made such movements; but Professor Thane, of University College, London, at the Congress in Copenhagen, very kindly drew my attention to another word, which is used in English, and, as far as I can learn, only in English. I find it in the text-books of Gray and Quain, and this word is *circumduction*. By Quain, circumduction is said to

¹ This *Journal*, vol. xix. p. 186.

² *Deutsche Zeitschrift für Chirurgie*, B. xx. p. 314, Leipsig, 1884.

be "the movement performed when the shaft of a long bone or a part of a limb describes a *cone*, the apex of which is placed in the joint at or near one extremity of the bone, while the sides and base of the cone are described by the rest of the moving part." If I had written in English, and had known this word, I should have hastened to use it, because it completely expresses my opinion, but we want that word in Norwegian as well as in German, and must say *rotiren*, *rotere*, or transcribe it. But in my book I did so (p. 76 and 77) when I said that "the lower portion of the ulna, from the great sigmoid cavity to the head of the bone, described the surface of a larger *cone*, and the olecranon that of a smaller one." When I (p. 77), immediately after the transcription, used the word *rotiren*, *rotate*, it must, for a Norwegian and a German, signify circumduction, and it is certain that I meant it so, which evidently is proved by the four curves (p. 73), which never could be obtained by simple rotation. I should suppose that the word circumduction is a very old word, perhaps formerly used on the Continent; but, though I passed seven of the last fourteen years on the Continent, and commonly in anatomical and surgical circles, I never heard that word, and



FIG. 1.—Male cadaver (thirty-two years old) left arm, the hand disarticulated. The humerus fixed by nails on a board. Into the middle of the head of the ulna is put a rod bearing a brush, wet with ink, at the styloid process of the radius is put a similar rod and brush, the bracelet of Lecomte put on, a complete pronation with supination *a-a'* as starting point is made, and the brushes made circumductional movements and wrote on paper the two curves, the smaller belonging to the ulna, both signifying the borders of the bases of two cones.

it seems, even in English, to be a little rare, because my honoured colleague Dwight does not use that splendid expression.

I am in this very moment working upon an illustrated treatise

on all the joints of man, and have found that the only two sorts of articular surfaces which allow circumduction are the saddle-joint and the ball and socket-joint. Now, I have made great models in wood giving the idea of the several joints as rotating bodies (*Umdrehungs Körper*). It is very easy to state from these models, or from natural bones, that one finds on the lower end of the humerus a combining of a ball and socket-joint for the radius and a saddle-joint for the ulna. It is not worth discussion, if we could have reached the same effect by two ball-joints or by two saddle-joints; the fact is, that we have the combination, and this combination allows a circumduction of the lower end as well of the radius as that of the ulna, but always in two different directions. The curve never gives the periphery of a whole circle, only a part of it. Commonly, when we use a gimlet or a corkscrew, the two bones give the two circumductional curves, as drawn in fig. 1; but we (the living subject) can by exercise circumduct alone the radius around the ulna (fig. 2);

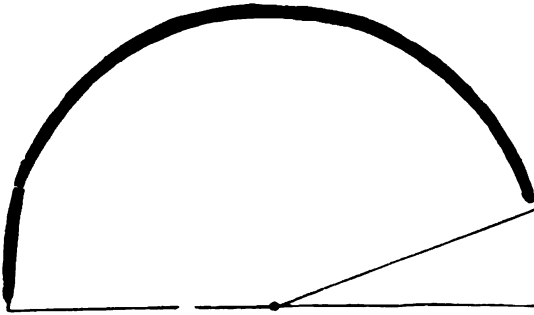


FIG. 2. —Female cadaver, thirty-three years old, left arm, the hand disarticulated, the humerus fixed by nails on a board. Into the middle of the head of the ulna is put a strong metallic rod, around which the radius is turned in circumduction. At the lateral end of the radius is put a rod bearing a brush and describing this curve, which represents a part of the periphery of the base of a cone.

and on the cadaver, but not on the living subject, by fixing the radius, we can circumduct the ulna alone around a point on the radius (fig. 3). In no case do we rotate the single bone, but we put them in a circumductional movement, and the single curve represents only a part of the whole periphery.

Certainly these two circumductional movements can have a

sort of common centre, especially to be seen in fig. 1; and it should not be impossible for me to instruct my workmen to execute a model in wood of a greater cone, into which was put laterally a smaller, but of the same length, and further other models, to let the radii of the bases of the cones vary in length from nothing until some few centimetres, and in this way give the most instructive imitation of that which may occur in nature when we let the different fingers form the different axes for the turnings of the hand.

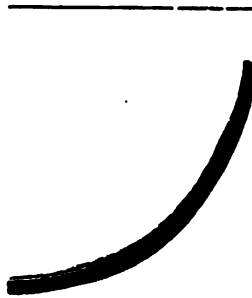


FIG. 3.—The same female cadaver as fig. 2, left arm, the hand disarticulated. Into the radius is put, through the whole length of the bone, a strong (4 mm.) metallic rod, and the ulna is turned in circumduction around this rod. At the middle of the head of the ulna—where the commonly described, so-called classical end of the axis for the movement of the radius (after Galenus and others) does run out—is put a rod bearing a brush, and has described this curve, which represents a part of the periphery of the base of a cone.

When Professor Dwight finds it rather surprising that the question should have raised no discussion, I must say that I have found sixteen journals reviewing the pamphlet in six languages, and the presenting of my models at the Congress of Copenhagen started one of the longest discussions, which lasted for several days, and will appear in the official report in a very short time.

I have tried to get a publisher for an edition in English of my book, putting all my engravings on wood free to his disposition, but vainly. Should I realise it, certainly I would take notice of all the worthful remarks of my honoured colleague Dwight.

THE NATURE OF LIGAMENTS. (PART III.) By J. BLAND
SUTTON, F.R.C.S., *Lecturer on Comparative Anatomy, and*
Senior Demonstrator of Anatomy, Middlesex Hospital Medical
School. (PLATE XII.)

ON two previous occasions attempts have been made and evidence has been adduced in this *Journal* (vols. xviii. and xix.) to show that there is reason to believe in the origin of many ligaments from the metamorphosis of muscles and tendons. The present paper contains the result of further inquiry into this question, particularly in regard to certain structures belonging to the knee-joint. After working out the chief facts in the evolution of the ligaments of this complex articulation, the details of which will be fully given later on, I was induced to examine the ligaments of the spinal column, particularly in relation to their ancestry. The greater number of these, as might have been expected, conform to the same mode of origin as the majority of those in the appendicular skeleton, but the consideration of the probable origin of the remarkable bands of yellow elastic tissue, familiar as the ligamenta subflava, has led me to certain conclusions exceedingly novel, and as unexpected as they are remarkable. It has been previously insisted upon that in the articulations of the appendicular skeleton, degenerate muscles play an important part in providing ligaments, yet in the axial skeleton the remains of very important structures, as well as functionless muscles, are turned to the same useful account by utilitarian Nature.

As the principal argument in this discussion concerning the nature of ligaments depends on the circumstance that muscles under certain conditions do degenerate into fibrous tissue, which tissue may become ligaments if occasions arise, the following examples may not appear redundant. In this *Journal* (vol. xiv.) Professor Watson describes the occurrence of the *curvatores coccygis* muscles in man. The muscles in question arose from the anterior surface of the sacrum between the third and fourth sacral foramina, also from the anterior surface of the body of the

fifth sacral vertebra. They were inserted into the front surface of the body of the second, third, and fourth coccygeal vertebræ.

The Professor then goes on to relate that Albinus, in his *Historiæ Musculorum*, p. 336, had noted this muscle in three subjects, but that in others they were replaced by ligamentous or tendinous fibres. The exact statement is: "Inveni eum in tribus; in alio imperfectionem et degenerantium; in aliis non musculo, sed ligamento simile." The extract is quoted here as affording excellent testimony to the degeneration of muscles into ligamentous tissue, from so famous an anatomist as Albinus (1734).

The bands of fibrous tissue passing from the lower sacral vertebræ to the coccyx, and known as the posterior sacro-coccygeal ligaments, represent in man the extensor coccygis of anthropomorphæ, or extensor of the caudal vertebræ of other animals. In man the place of these ligaments is occasionally occupied by muscles, the attachments of which are thus described by Hyrtl:—

"The muscles are found between the hinder surface of the sacral vertebræ and the last piece of the coccyx. They are a pair of tendinous muscles, repetition of a muscle which appears in most mammals—a *sacro-coccygeus posticus seu extensor coccygis* (*Lehrbuch der Anatomie*, p. 487).

The preceding cases serve as excellent illustrations of the rules to be followed in forming conclusions as to whether any particular band of fibrous tissue represents a degenerated muscle:—

1. It must correspond with its presumed representative in origin and insertion.
2. The muscle should occasionally reappear as an anomaly in the human subject and replace the fibrous tissue.
3. Failing Rule 2, the muscle should assume a functional importance in other animals.

If Rules 1 and 2 be satisfied, the assumption that a given fibrous band represents the muscle is reasonable; if the third rule be sustained, the evidence is then very strong, and becomes almost a certainty.

If Rules 1 and 2 be not satisfied, the notion of representation should be entertained with caution. In all instances recorded in this and my preceding papers on the subject, these conditions

have been fulfilled, and in the majority the three rules have been carried out, and further testimony also adduced in support of the conclusions set forth.

Thus—(1) The place of the *curvator coccygis* is occasionally occupied by a fibrous band. (2) This band is occasionally replaced by the *curvator* as a functional muscle; it is then regarded as an anomalous structure. (3) The *curvatores coccygis*, as seen in man, are representatives in him of the *depressores caudæ* present in very many of the lower mammals.

A good instance of regression of a muscle may be found between the atlas and par-occipital process of the occipital bone.

Filling up the spaces between the transverse processes of the cervical vertebræ is a series of small muscles known as the *intertransversales*. Two of these exist in each space, being attached to the anterior and posterior bony arches which form the foramina for the vertebral artery; the anterior spinal nerves pass out between them.

Passing upwards from the atlas to the occipital bone we find only one *intertransversalis* muscle, and that an anterior one, denominated in this situation the *rectus capitis lateralis*. Its posterior companion is represented by a fibrous band commonly known as the *lateral occipito-atlantal* ligament, but named by Professor Humphry the *posterior oblique ligament*. This bond fulfils most of the required conditions requisite for being considered a degenerate intertransverse muscle, for it arises from the posterior part of the lateral mass of the atlas, lies behind the vertebral artery, and has the suboccipital nerve (first cervical) separating it from the *rectus capitis lateralis*. In the majority of animals we do not find two distinct *intertransversales* muscles between the vertebræ, but one broad muscle; and at the atlas the *rectus capitis lateralis* is a muscle of considerable size, extending from the lateral mass of the atlas to the par-occipital process, thus occupying the situation of *rectus capitis lateralis* and the *posterior oblique ligament*.

The most extensive collection of ligaments arising from the disuse of muscles is probably to be found between the processes of the cervical vertebræ in whales. In these mammals, in the adult state, the neck vertebræ fuse into a solid mass, hence the intervertebral muscles become useless.

Professor Struthers, in this *Journal* (vol. vii., 1873), contributed a paper "On the Cervical Vertebrae and their Articulations in Fin-whales," in which he has given an interesting and detailed description of the massive ligaments found between these vertebrae, which leaves little doubt in my mind that they arise from the degeneration of the muscles usually occupying these situations in other animals.

An excellent example of regression of a muscle is afforded by the *epitrochleo-anconeus*, a small muscle frequently present in the human subject. It arises from the back of the internal condyle of the humerus, and is inserted along the inner border of the olecranon. It lies over the ulnar nerve. This muscle has been elaborately investigated by Gruber. An excellent review of the literature, with some interesting remarks and additional instances of its occurrence, will be found in this *Journal* (vol. ix.), by Mr J. C. Galton. The muscle is exceedingly common among mammals. Concerning its presence in man, Mr Galton makes the following admirable remarks:—

"Though I will readily concede that the epitrochleo-anconeus may in man be occasionally adjutant to the triceps, it seems to be rather a straining after a τέλος to assume that any function other than an active one should be accredited to a muscle rather than it should be simply deemed rudimentary. For I cannot help regarding the function of an organ but as dependent upon its physical capacity, and could as soon conceive of a ligament taking upon itself the active duties of a muscle, as of the latter enacting the passive rôle of its far less highly organised coadjutor. Better declare at once that a purely muscular slip is functionless than assume that it exercises the office of protecting a nerve from external injury.

"Seeing, then, that this muscle has been found so frequently in all the lower mammals, and that it is so invariably present in an order—and that, too, one of the lowest¹—the myology of which, at any rate, has been most carefully studied, while it becomes less frequent among the lower Primates, to finally disappear among the anthropoid apes, and only to emerge again occasionally in man as an 'anomaly,' we have reason for regarding it, as we do such a structure as the supracondyloid

¹ The author here refers to the Edentata.

process, as a now almost functionally useless heirloom, which has descended to us from very remote ancestors."

A careful examination of the region of the olecranon in man has enabled me to come to the following conclusions, viz., that even when the *epitrochleo-anconæus* is not represented as a muscle, its place is occupied by a collection of fibrous tissue exactly recalling the shape of the muscle, and forming a bridge from the internal condyle to the olecranon, under which passes the ulnar nerve. Often reddish fibres of muscular tissue may be demonstrated in this fibrous arch.

In the accompanying figures, fig. 2 represents the epitrochleo-



FIG. 1.

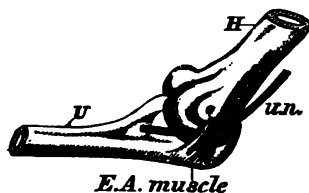


FIG. 2.

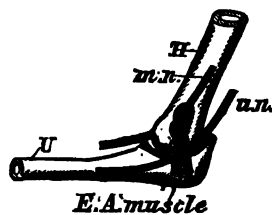


FIG. 3.

anconæus as it occurs in man. Fig. 1 shows it replaced by a tract of fibrous tissue—the usual condition. Fig. 3 represents the elbow-joint of a Virginian opossum, in whom this muscle constantly occurs.

One of the most convincing cases concerning the degeneration of a muscle into fibrous tissue that I have seen occurred in the heart of a deer, the wood brocket (*Cariacus nemorivagus*). In this creature the moderator band which usually unites the opposite walls of the right ventricle, and is normally of well-developed muscular tissue throughout, was in this case converted into a dense band of fibrous tissue.

The Lumbar Aponeurosis.

Under this name human anatomists have found it convenient to describe three stout layers of fascia ensheathing the erector spinæ and quadratus lumborum muscles.

The *superficial layer* springs from the spines of the lumbar vertebræ and the posterior part of the iliac crest. After closely investing the erector spinæ, it joins with the middle layer of the aponeurosis at the outer border of that muscle.

The *middle layer* springs, by strong fibrous bundles, from the tips of the transverse processes of the lumbar vertebræ; and, passing between the erector spinæ and quadratus lumborum muscles, blends with the posterior layer, as already described, and forms a strong tendon of origin for the transversalis abdominis muscle.

The *anterior layer* of the lumbar aponeurosis is attached to the front of the transverse processes of the lumbar vertebræ, covers the anterior surface of the quadratus lumborum muscle, and blends with the middle layer of fascia. Thus the anterior layer blends with middle at the outer border of the quadratus lumborum, whereas the posterior and middle layers of the aponeurosis blend at the outer border of the erector spinæ muscle.

Careful inquiry into the comparative anatomy of the *posterior* layer of the aponeurosis makes it evident that it arises from the metamorphosis of the lower fibres of the *latissimus dorsi* muscle; for in many animals this fascia is wholly replaced by muscle-fibres continuous with the latissimus dorsi sheet. The same mode of origin may be maintained for the anterior aponeurosis of the external oblique, internal oblique, and transversalis muscles, also the resplendent tendon of the serrati postici superior and inferior, and the rhomboids. Even the central tendon of the diaphragm has arisen from the metamorphosis of its muscular fibres; for in the porpoise there is no trace of tendon, but it is muscular in structure throughout the whole of its extent.

The middle layer of the lumbar aponeurosis has a very curious origin. If a recent subject be chosen, and the muscles of the loin be removed down to the middle layer of the lumbar aponeurosis, care being taken not to injure the fascia, there will be

seen arising from the tips of the transverse processes of the three upper lumbar vertebræ a fan-shaped arrangement of fine fasciculi composed of fibrous tissue, but more elastic in character than the rest of the aponeurosis, and strongly recalling in appearance the nacreous-looking fibres of origin of the serratus posticus inferior muscle. These fan-shaped masses have a direction downwards and outwards, the apex being attached to the tip of the transverse process exactly like a levator costæ muscle, and there can be little doubt that these thickenings in the middle layer of the lumbar fascia are the degenerate remains of a set of muscles in continuation of the levatores costarum series. These fan-shaped collections of tissue in the middle layer of the transversalis aponeurosis are by no means occasional, but may be demonstrated in any dissecting-room subject with ordinary care.

That these thickened bands really represent the degenerate remains of levatores costarum muscles, the following facts will serve to prove beyond a doubt.

In a male subject dissected in my room at the Middlesex Hospital this winter, a lumbar rib was detected in connection with the transverse process of the first lumbar vertebra. In this case a levator costæ muscle arose from the tip of the transverse process of the twelfth dorsal vertebra, and was inserted into the rudimentary rib below, making in all thirteen of these muscles on the right side. Hence it seems very clear in this case that we have to deal with an instance in which one of these muscles, usually represented by fibrous tissue, had resumed a functional condition in consequence of the presence of a supernumerary rib. The shape, arrangement, and general relations of the muscles and fascia in this case are shown in fig. 4. This fact fits in well with the current opinion that the internal and external oblique muscles of the abdomen are the representatives of the internal and external intercostal muscles of animals possessing lumbar ribs, *e.g.*, lizards and crocodiles. There seems to be little doubt that the ilio-lumbar ligament, which arises from the transverse process of the fifth lumbar vertebra and is inserted into the crest of the ilium, is really the degenerated levator costæ belonging to that vertebra. Attention must now be directed to the anterior layer of fascia—that which is nearest the peritoneum. If the abdo-

minal cavity of a lizard be examined, it will be seen that immediately beneath the peritoneal lining, and in close union with the serous membrane, is a definite layer of muscular tissue which in the ventral part strongly recalls the transversalis muscle, but posteriorly differs from that structure in that it extends quite up

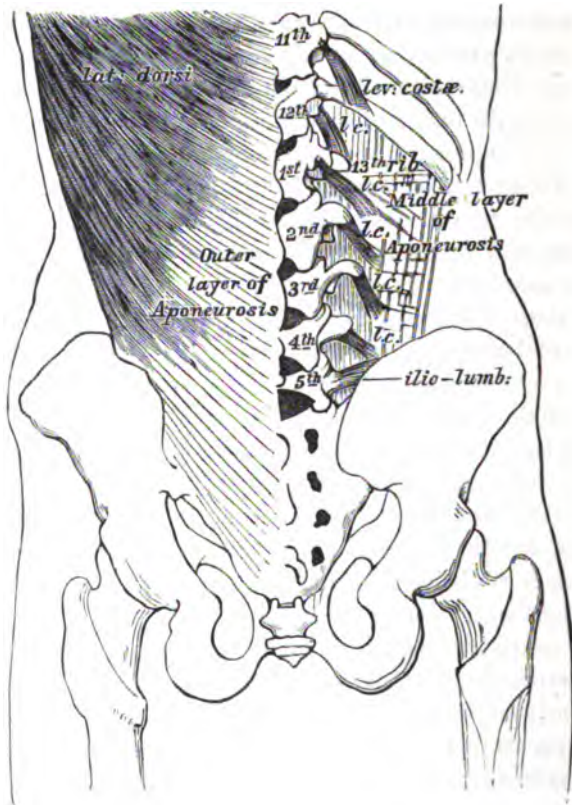


FIG. 4.

to the vertebræ and passes anteriorly into the thorax, giving off digitations to find attachment to the inner surface of the ribs, very much resembling in this respect the mode of origin of the serratus magnus muscle on the outside. Another feature of interest concerning this muscle may be mentioned. Mivart, in his *Elementary Anatomy*, p. 300, points out that—"In reptiles — e.g., Iguana—a muscle, the *retrahentes costarum* (which

appears to have no representative in man), arises by muscular fibres from the sides of the bodies of the trunk vertebræ, and is united by aponeurosis with the sides of the seventh and eighth cervical ribs and into the seven following ribs. In tailed batrachians, such as *Menopoma*, this muscle is very fleshy, and its anterior end is carried forwards beneath the basis cranii.

A careful examination of the muscle, called by Mivart the *retrahentes costarum*, and later by Professor Humphry referred to as the *subvertebral rectus* (in his account of the myology of the *Cryptobranchus japonicus*), has convinced me that it is nothing more than a segmentation of that portion of the transversalis adjacent to the vertebral column, the digitations of which in many forms—*e.g.*, siren, iguana, chameleon, *Cryp'to-branchus*, and many others—have acquired an insertion into the ribs near their angles.

In the possession of a complete diaphragm, man agrees with all mammals, but differs from all other animals below this class.

A careful study of the arrangement of the abdominal muscles, particularly in lizards, has served to convince me that the diaphragm has been derived from an original extension into the thorax of the transversalis abdominis muscle. This conception is by no means new, for I find that Professor Humphry has published the following view of the matter in this *Journal* (vol. vi. p. 18): "There can, I think, be little doubt that the *crura* of the *diaphragm* in mammals are formed by the lumbar parts of the *sub-vertebral rectus* bending downwards on the sides of the aorta and encircling it, and that the lateral parts of the diaphragm are in like manner formed by the inflection of the lateral parts—the *depressores costarum* and *transversalis*—of the same sheet."

For my own part, rather than complicate matters by introducing as separate muscles what are really differentiations of one and the same sheet, I consider all that muscular layer on the inner aspect of the ribs as the *transversalis*.

In order to make myself clear on this point, fig. 1 on Plate XII. will afford assistance. It represents an inner view of the left half of the anterior portion of the body of a lizard (*Uromastix hardwickii*). The transversalis will be easily recognised extending from the pelvis to the first thoracic rib, and laterally to the middle line in the abdomen, but in the thorax it terminates at

the sides of the sternum. The abdominal part in the lizard is sharply marked off by the intense black colour of the peritoneum (this has been represented in the drawing by deeper shading). Beyond this point the muscle will be seen spreading itself over the ribs, and at its anterior part the digitations may be easily seen passing to the rib shafts. The digitate portions are worthy attention, for in their origin, direction of the fibres, and insertion, they exactly recall the disposition of the occasional subcostal muscles of human myology, which, when present, are most frequently found near the angles of the ribs on the inner aspect of the thorax.

A critical examination of this extensive muscular layer induces me to offer this explanation:—

The inferior or ventral portion of this muscle corresponds to the transversalis muscle of human anatomy, its *upper or dorsal fibres are represented by the anterior layer of the lumbar aponeurosis*. The extreme anterior portions which are attached to the inner surface of the foremost ribs are occasionally represented in man by the variable sub- or infra-costal muscles, whilst the intermediate portion in mammals forms that characteristic structure in mammalian myology, the diaphragm; and the structures known as the ligamentum arcuatum internum and externum may easily be conceived as arising from the tendinous metamorphosis of a few fibres of the muscular sheet, lying between the transversalis muscle and the diaphragm.

We must now return to the transversalis aponeurosis. Briefly stated, the origin of this threefold aponeurosis would seem to be this:—

- (a) The *posterior* layer results from the metamorphosis of the lower fasciculi of the *latissimus dorsi* muscle.
- (b) The *middle layer* contains degenerate elements of the lower representatives of the *levator costarum* series of muscles, one of which forms the ilio-lumbar ligament, and possibly this sheet of fascia is made up entirely in this way.
- (c) The *anterior layer* is the representative of the *posterior* portion of the transversalis muscle, which in lizards, *e.g.*, *Uromastix*, *Hatteria*, &c., extends as a muscle from the vertebral centra.

In that man possesses in the posterior and anterior regions of the trunk—for there can be little reasonable doubt that the so-called aponeurosis of the oblique and transversalis muscles really result from the metamorphosis of the fasciculi of those muscles—large sheets of tissue composed of minute glistening tendons, he contrasts markedly with amphibians, lizards, and ophidians, in whom these aponeurotic tracts are represented by sheets of well-developed muscular tissue.

The Knee-Joint.

It is proposed in the next few pages to give a brief outline of the probable evolution of the various fibro-cartilages, ligaments, and synovial membranes of this complex articulation, which has been the subject of so much interesting discussion from time to time.

In a previous paper (this *Journal*, vol. xviii. p. 225), it was shown that the external lateral ligament of the knee-joint in man was the divorced tendon of the peroneus longus muscle. This deduction was strengthened by the fact that in the gibbon (*Hylobates leuciscus*), the peroneus longus muscle arises tendinous from the femur, the tendon itself taking the place of the external ligament, but lacks a direct attachment to the head of the fibula. I have been able to confirm this observation on a second specimen of the silvery gibbon (*H. leuciscus*), thus proving it to be a normal condition. In the curious West African potto (*Perodicticus potto*), the relations of the muscle and ligament are very intimate, and nearly resemble those of the gibbon. A precisely similar condition exists in the knee-joint of the beaver. The internal lateral ligament is derived from the original tendon of insertion of the adductor magnus muscle, and it is one of the common-place facts in human myology, that the anterior ligament is the tendon of the quadriceps extensor of the thigh.

Some months later, in a second paper (this *Journal*, vol. xix. p. 17), it was suggested that in all probability the semimembranosus muscle would be found responsible for the internal interarticular fibro-cartilage. These structures, with the crucial ligaments, will be fully considered, and an endeavour will be made to work out fully the history of the singular ligaments of this important articulation as they present themselves in man.

If one of the tailed batrachians be examined, and *Menobranchus lateralis* will serve as an excellent example, we shall find the knee-joint deficient in crucial ligaments and inter-articular fibro-cartilages, so that in this creature we have a very good starting-point.

On looking closely into the myology of these amphibians, a curious fact at once becomes evident that, whereas in mammals, and in man especially, the muscles destined for the pes take origin with very few exceptions from the tibia and fibula, in these creatures they arise almost exclusively from the femur. This is significant, and clearly indicates that it is in the forms filling up the gap between Urodele batrachians and the lowest mammals that we must seek for an explanation of the changes which ensue round about the knee-joint, in order to elucidate the peculiar arrangement of the ligaments, &c., in the knee-joint of those which give "suck to their young," and in this way work upwards to man.

In our first ascensive step we are encountered by the frogs, who startle us with the richness of the musculature of their limbs, for in many respects myological differentiation in them surpasses that which pertains even in man.

On examining the knee-joint of a frog, it will be found to possess interarticular fibro-cartilages and crucial ligaments, but these structures differ in a very important manner from those of mammals.

In the first place, the interarticular fibro-cartilages are directly continuous with the tendons of muscles; the inner cartilage is in direct continuity with a muscular mass corresponding to the semimembranosus. This muscle is usually described as being inserted into the back of the head of the tibia, but the main mass will be found inseparably associated with the cartilage, as I have described. The external fibro-cartilage is not well formed, and seems rather to be a continuation of the inner one than as representing a discrete element of the knee-joint, such as we find in higher forms.

The crucial ligaments are not such distinct structures as are found usually in animals possessing them, but they seem to be made up of prolongations of connective tissue and tendon from the various muscles arising from the condyles of the femur, such

as the gastrocnemius, tibialis anticus, posticus, extensor cruris brevis, &c.

The question at once suggests itself—Why should so much difference prevail in the anatomy of this joint in animals so closely related as Urodeles and Anoura?

Dr Gadow, in his instructive paper on "Comparative Myology" (this *Journal*, vol. xvi. p. 501), to which I have so often referred, writes:—

"We must remember that the change of an aquatic animal, which used its limbs simply like paddles, into a semi-aquatic and partly terrestrial, and therefore crawling, creeping, and running creature, involved a complete change of its muscles, and at a later period of its bony framework. In swimming animals, such as ceratodus and menobranchus, the longitudinal axis of the whole limb is nearly straight, whilst a terrestrial life necessitates the bending of a limb at several angles, and the development of more or less complicated joints."

It is this flexion which explains how tendons outside the joint in animals whose limbs are nearly straight get drawn into the joint when the limb is acutely bent.

When the leg is extended, the anterior surfaces of the femur and tibia are in the same plane; when the leg is flexed, the broad upper surface of the tibia is brought into contact with the lower part of the posterior surface of the femoral shaft, and immediately in relation with the tendons of origin of the muscles destined for the foot, and in many cases with muscular tissue itself.

Therefore in menobranchus, the axis of whose hind limb is nearly straight, the tendons are excluded from the joint, and arise from the femur. In the frogs, whose limbs are flexed, the tendons of origin of many of the leg muscles intruding upon the joint get drawn between the opposed surfaces of the tibia and femur, constituting fibro-cartilages, crucial ligaments, and lateral ligaments, as the case may be.

For a long time I suspected that the fibro-cartilages of the knee-joint might possibly represent an aborted segment in the limb, for in some lizards (*Teius teguexin* and *Uromastix*) these discs contain bone. Further research, however, shows conclusively that the fibro-cartilages are tendons of muscles, and that

in many lizards a sesamoid bone develops in them (see Plate XII. fig. 4).

The crucial ligaments must now be considered. It has previously been shown that the region of the knee-joint has been the seat of very considerable disturbance among the muscles. For example, in primitive forms, like lepidosiren, the muscular layers, pass from the trunk and invest the limbs without any transverse segmentation occurring. In frogs, lizards, and crocodiles, a gap occurs in the muscular sheet, the proximal segments attaching themselves to the tibia, the distal muscles arising from the lower end of the femur. In this way the quadriceps extensor, sartorius, gracilis, the hamstring group, and the adductor magnus, become inserted into the tibia; whilst the extensors and flexors of the digits, the peroneal group, gastrocnemius, plantaris, tibialis anticus, and posticus, arise from the femur.

Later migration¹ occurred whereby many of the muscles shifted their insertion from the tibia and formed a new attachment to the femur, *e.g.*, the adductor magnus.

On the other hand, many muscles left their acquired origin from the femur and descended to new attachments on the tibia and fibula (migration). Hence it is necessary to decide whether a given ligament of the knee-joint has had its origin from one of the thigh muscles shifting its insertion, or from one of the leg muscles migrating to the tibia or fibula from the femur.

Both these processes have been in operation, and in a previous paper evidence was adduced to support the view that the internal lateral ligament was originally the tendon of the peroneus longus, which muscle has migrated from the femur to the fibula; whilst the internal lateral ligament results from the adductor magnus muscle withdrawing its point of insertion from the tibia to the femur.

There can be little doubt that the crucial ligaments have a similar origin, but it is not quite clear to which muscles they originally belonged. It is possible to limit the muscles to three or four to which they may have been attached. The long extensor of the toes and the tibialis anticus muscle arise in many animals from the femur when crucial ligaments are present, so that they may be excluded satisfactorily enough. The muscles on which the

¹ For explanation of this term, *vide* vol. xix. p. 41.

lot falls are the tibialis posticus, flexor longus, and the extensor brevis digitorum; for though the last muscle arises in man and many other animals from the dorsum of the foot, yet in Monotremata and several of the Phalangista it takes origin in part from the upper extremity of the fibula. To which of these muscles the crucials originally belonged it is difficult to decide; but I am strongly inclined to the view that the tibialis posticus is the source of the posterior crucial ligament. In a young specimen of the sharp-nosed crocodile I obtained for dissection, the fibres of the tibialis posticus could be clearly seen passing upwards in continuity with the posterior crucial ligament, but this is the only instance in which such continuity could be detected. There is one other possible claimant for association with these ligaments, and this is the peroneo-tibial muscle. It occurred to me that as this muscle, in sphendon, menopoma, menobanchus, the wombat, and others, fills up the gap between the tibia and fibula, it might in some of the associated forms be found extending even to these ligaments, and so on to the femur; although a great number of dissections have been conducted with this object in view, the verdict rests altogether in favour of the tibialis posticus being the parent muscle.

The synovial membrane must now be considered. If the knee-joint of a colt be dissected with care, it will be found that instead of the articular surface of the patella forming the anterior boundary of that joint, as it does in man, it is excluded from the articulation by a septum of fibrous tissue; in fact, the patella, like other sesamoid bones, glides between the condyles of the femur, and is surrounded by its own peculiar bursa. The same condition is met with in other ruminants.

In adult horses the bursa communicates with the synovial cavity of the joint by means of a small foramen.

In the beaver the arrangement of the synovial membranes of the knee-joint is after this fashion. There is a distinct synovial pouch for the patella and the patellar surface of the femur. The cavity for the articular surfaces of the femur and tibia is divided into two parts by the crucial ligaments and a septum of connective tissue, thus making three synovial membranes in all: one for the patella, and one for each femoral condyle and the corresponding articular surface on the head of the tibia.

In man, however, this septum disappears, save a few strong fibres in the middle line, which pass from the lower border of the patella to the intercondyloid notch immediately below the patellar facet. This band of tissue, with its lateral fringes, adipose and fibrous in structure, is denominated in human anatomy the *ligamentum mucosum* with the *ligamenta alaria*. In reality they are simply vestiges of the sac-wall of the bursa, originally developed between the patella and the femoral condyles.

Examine a human foetus at the ninth month, or even early, by dividing the knee-joint vertically, as in Plate XII. fig. 5. The synovial membrane will be found arranged as follows:—The proper cavity ends on a level with the upper border of the articular cartilage of the femur. Immediately above this, and lying behind the quadriceps extensor muscles, is a large bursa, whose sac communicates with that of the knee joint proper by a small opening in its lower part. After birth, however, the diaphragm between the two cavities quickly disappears; the synovial membrane of the joint and the bursa blend to form one common cavity. Thus it follows that the large cul-de-sac of synovial membrane extending under the extensor muscles of the thigh is due to secondary causes. It has also been shown that this has occurred in connection with the patella, so that the knee-joint, as seen in man, is made up of its own synovial membrane reinforced by two very considerable bursæ.

Viewed in full light the evolution of the structures concerned in man's knee-joint may be considered as resulting from the changes produced by the retrogression and migration of muscles to provide it with ligaments. The metamorphosis of tendon to furnish it with interarticular fibro-cartilages, and lastly the annexation of bursæ to extend the dimensions of its synovial territory.¹

The chief features in the curious history of this remarkable joint are visually represented in Plate XII. figs. 2, 3, 4, 5, and 6.

It must not be forgotten that intricate as is the knee-joint in man, it is surpassed in complexity by the corresponding articu-

¹ Professor Macalister has come to similar conclusions in a short paper "On the Morphology of Joints," read before the Royal Irish Academy, February 1883.

lation of birds. This is chiefly brought about on account of the fibula extending above the tibia, and articulating with a groove in the outer condyle of the femur.

For convenience, the origin of the various structures of the knee-joint may be arranged in a tabular form:—

Lateral Ligaments.

Internal,	.	.	.	Tendon of the adductor magnus muscle.
External,	.	.	.	Tendon of the peroneus longus.

Fibro-Cartilages.

Internal,	.	.	.	From the tendon of the semi-membranosus muscle.
External,	.	.	.	Tendon of the popliteus.

Crucials.

Anterior,	.	.	.	There are no certain facts as to which muscle it originally belonged.
Posterior,	.	.	.	Tibialis posticus muscle.

Synovial Membrane.

The great cul-de-sac,	.	.	Original bursa between the quadriceps extensor and the femur.
Middle portion,	.	.	The original patellar bursal sac.
Lig. mucosum and alaria,	.	.	The remains of the original sac-wall of the patellar bursa.

THE LIGAMENTS OF THE VERTEBRAL COLUMN.

The spinal column abounds in ligaments, some passing between the various segments of the spine, others from individual vertebræ to the ribs, and so on. The most cursory glance at such ligaments as the interspinous, and in the dorsal region the intertransversales, must convince any observer that they are really fibrous representatives of a very considerable portion of the muscles, interspinales, and intertransversales, which occupy corresponding positions in the cervical and lumbar regions of the column.

So, too, in respect of the ligaments connecting the heads and tubercles of the ribs with the vertebræ, viz., the anterior and posterior costo-transverse, and the stellate ligaments, they doubtless represent what were at one time muscles; indeed, in

many animals we find muscles occupying corresponding positions. As the origin of these ligaments is so evident, they need not detain us any longer, and we must pass on to consider the *ligamenta subflava*, of which it is not too much to say "they are brimful of interest."

The Ligamenta Subflava.

When describing the *ligamentum conjugale costarum* in this *Journal* (vol. xviii. p. 225), it was suggested that in all probability this structure represented a portion of a suppressed vertebral segment. Whilst engaged in looking more closely into this matter, I was led to observe the significance of those singular plates of yellow elastic tissue, which alternate with the laminae of the vertebræ in mammalia, and are known as the *ligamenta subflava*, or *lig. intercruralia*.

If the vertebral column of a cartilaginous fish, such as the skate, be examined, it will be found to present the following characters:—The centrum of each vertebra is a cylindrical body, with each end deeply concave—in a word, amphicæalous. The ends of each centrum meet with its fellows in front and behind, so that between any two vertebræ a hollow exists, filled in with gelatinous tissue, the remains of the notochord.

The transverse processes are represented by rods of cartilage proceeding from either side of the centra. Standing on each side of the dorsal surface of each centrum is a small triangular plate known as the neural process. This presents a foramen for the transmission of the *ventral* root of a spinal nerve.

Fitting in between the neural processes, and coming into relation with the space between contiguous centra, may be seen hexagonal plates of cartilage, known as the interneural plates, which, in most parts of the column, complete the neural arches, and fill up at the same time the spaces corresponding to the intervertebral foramina in a mammal's spine. Each of these plates is pierced for the transmission of the *dorsal* root of the spinal nerve, whose ventral root traversed the neural process immediately anterior to it.

Alternating with the interneural plates, but corresponding with the neural processes, and consequently with the centra of the vertebræ, may be seen other plates of cartilage, known as

the neural spines. The lower part of the neural spine resembles an inverted Y. The two arms of the letter join with the interneural plates in front and behind it; in exceptional cases the neural spine may unite directly with the neural process, as shown at *sp* in Plate XII. fig. 7.

If the arrangement represented in fig. 7 be attentively considered, it becomes evident that the vertebral column of the skate is made up of a series of alternating segments; thus we have a vertebral centrum, with its neural process, neural spine, and associated nerve, the ventral root of a spinal nerve. To this succeeds a segment made up of a gelatinous tissue, the embryonic notochord, in relation with an interneural plate, with a correlated nerve, the dorsal root of a spinal nerve.

Leaving the cartilaginous fishes for a space, we pass to the vertebral column of man. In him, as in the skate, the spine is made up of a series of alternating segments. Thus we have a centrum, with its neural processes, the pedicles, surmounted by the neural spines; to this succeeds an intervertebral disc, with its pulpy nucleus and an interneural plate, a *ligamentum subflavum*. All this exactly as in the skate; but now comes the question of nerves.

There are no morphological guides so safe and so reliable as nerves. Now and then they lead the anatomist from the true path, but they are valuable in the extreme as good interpreters, and afford guidance in the decipherings of the morphologists.

It is now well known to embryologists that the dorsal roots of the spinal nerves in the elasmobranch fishes not only arise from the spinal cord earlier than the ventral roots, but alternate with them, this alternation of the dorsal and ventral roots being maintained even in adult life (*vide* Plate XII. fig. 8). Thus the embryological history and normal arrangement of the spinal nerves in sharks and rays affords distinct evidence of segmentation. The ventral roots correspond with the vertebral centra, whilst the dorsal roots harmonise with the intervertebral segments and their associated ligamenta subflava.

Any one reading these statements will at once observe that my intention is to put forward the opinion that the ligamenta subflava, as seen in mammals, including man, are direct descendants

of the interneural plates present in the spinal column of a skate. Such is my object, and in support of the view further evidence will now be adduced.

Passing from elasmobranchs to teleosteans (bony fish, such as the perch, pike, &c.), we find the interneural plates wanting, their place being supplied by ordinary fibrous tissue. This alteration of texture at once raises the question—Can a structure, such as an interneural plate in one animal, be represented by fibrous tissue in another? Of this we have a very excellent example in man himself. In the early foetus the rod of cartilage known as Meckel's cartilage extends from the malleus to the symphysis menti; but in adult life it is merely represented by the fibrous ligament known as the long internal lateral ligament of the lower jaw. The cartilage atrophies, but its sheath thickens and becomes ligamentous.

Many other examples could be adduced were they necessary to establish the point. Another question forces itself for consideration. The ligaments now being discussed are formed of fibrous tissue in teleosteans, but in birds, in man, and in other mammals, they are composed of yellow elastic tissue. May these two substances be regarded as convertible? The following is evidence in favour of this view:—In many mammals—notably the horse, elephant, ox, sheep, and very many others—we find a *ligamentum nuchæ* passing from the occiput to the spines of many of the vertebræ. In the giraffe it extends even to the sacrum. This ligament in the mammals mentioned is famous for presenting yellow elastic tissue in its most typical condition; yet in man this very remarkable ligament is represented by a tract of fibrous tissue. Thus in many animals low in the scale we find fibrous tissue passing from occiput to the spine, usually of the seventh cervical vertebræ, then in other animals—*e.g.*, the horse, where resilience is required—yellow elastic tissue appears in abundance, to disappear, when it is no longer required for its elastic properties, in animals higher in the scale, even in man himself. All these changes may be observed in the class *mammalia*.

With this evidence before us, it may not appear unreasonable to suppose that the interneural plates in the vertebral column of elasmobranchs are represented by fibrous ligaments in the

teleostean fishes and in the spine of mammals by the well-known ligamenta subflava. Further, if nerves are to be trusted as guides, the vertebral column is made of alternating segments, each being composed as follows :—

A vertebral body with the pedicles, laminae, and spinous process, its associated nerve being the ventral root of a spinal nerve.

The second segment is made up of the remains of a section of the notochord, surrounded by dense fibrous tissue (the intervertebral disc of mammals). Posteriorly it has an interneural plate in elasmobranchs, fibrous tissue in teleosteans, and yellow elastic tissue (ligamentum subflavum) in mammals, the associated nerve being the dorsal root of a spinal nerve.

Lastly, the intervertebral disc is not by any means a simple structure. The various factors entering into its composition are represented in Plate XII. fig. 9. In the centre is the pulpy remains of the notochord, surrounded by fibrous tissue, the thickened remains of the notochordal sheath. The posterior border of the disc is made up, or rather extended, by the fusion with it of the median portion of the ligamentum conjugale costarum, ending on either side as the interosseous ligament attached to the heads of the corresponding ribs.

It will now be convenient to arrange the spinal ligaments dealt with in this paper, and their ancestry in a tabular form :—

Ligaments of the Spine.

Intertransverse ligaments of the dorsal region, . . .	Intertransverse muscles in the cervical and lumbar regions.
Lat. occipito-atlantal, . . .	Rectus capitis lateralis (posterior fibres).
Interspinous, . . .	Interspinales muscles in the cervical region.
Ilio-lumbar, . . .	Levator costae muscle.
Anterior and posterior costovertebral, . . .	Muscles of the back.
Interosseous of rib-heads, . . .	Lig. conjugale costarum.
Lig. subflava, . . .	Are in mammals the representatives of the interneural plates of sharks, rays, &c.

The Gleno-humeral Ligament.

In the second paper, attention was drawn to the occurrence in the shoulder-joint of some mammals of the gleno-humeral band in such a well-marked degree as to constitute a veritable liga-

mentum teres. The animals included in the previous list were the wombat, galago, opossum, hedgehog, and chlamydophorous. To this list must be added the tree-porcupine (*Sphingurus prehensilis*), the vulpine phalanger (*Phalangista vulpina*), the crab-eating opossum (*Didelphys cancrivora*), and the beaver (*Castor canadensis*), the prairie marmot (*Cynomys ludovicianus*), the mole (*Talpa europea*), and the Canadian porcupine (*Erethizon dorsatus*).

In the case of the vulpine phalanger, it was so large as to exceed the tendon of the biceps in transverse section. In the case of the beaver, the gleno-humeral ligament was as large as the ligamentum teres in that animal's hip-joint. In order to see this ligament satisfactorily in any animal, all the muscles in contact with the capsule should be removed and the joint opened from the outer side. If a gleno-humeral ligament be present, it will be at once recognised running parallel with the long tendon of the biceps, stretching from the base of the coracoid process to the lesser tuberosity of the humerus.

The relations of the coraco- and gleno-humeral bands, and the long tendon of the biceps to the capsule of the shoulder-joint and to one another, are represented on Plate XII. fig. 10.

SUMMARY.

Having attempted to work out the origin of some of the chief ligamentous and fibrous tracts of the human body, it will be useful to condense the result of the inquiry in the form of a summary.

1. *Fibrous tracts and ligaments resulting from the degeneration of muscles* :—

- (a) In the axial skeleton. The interspinous, intertransverse, post. oblique of the occipito-atlantal set, coccygeal, rhomboids, anterior and posterior costo-transverse, the middle layer of the lumbar aponeurosis, ilio-lumbar, the lig. arcuatum internum and externum, and the temporo-maxillary fibro-cartilage.
- (b) In the appendicular skeleton we have the rhomboid, conoid, trapezoid, gleno-humeral bands, the internal brachial ligament, epitrochleo-anconeal fascia, interosseous membrane of the fore-arm, and palmar fascia.

The great sacro-sciatic ligaments, anterior thick portion

of the capsule of the hip-joint, the interosseous membrane of the leg, the superior tibio-fibular ligaments, and the plantar fascia.

2. *Ligaments and aponeurotic tracts arising from tendons*, include the following :—

- (a) Axial skeleton. The anterior and posterior layers of the lumbar aponeuroses, central tendon of the diaphragm, aponeuroses of internal, external oblique, and transversalis muscles.
- (b) Appendicular skeleton. The gleno-humeral lig., the ligamentum teres, the internal, external, and crucial ligaments of the knee, with the semilunar fibro-cartilages. The internal and external lateral ligaments of the ankle-joint, the calcaneo-scaphoid, and the long and short plantar ligaments.

3. *Skeletal elements represented by fibrous and elastic tissue.*

- (a) Axial skeleton. The check, transverse, suspensory, posterior occipito-atlantal and atlo-axoid ligaments. The intervertebral discs, interosseous lig. of the rib heads and the ligamenta subflava. The long internal lateral of the lower jaw, the stylo-hyoid and anterior lig. of the malleus.
- (b) Appendicular skeleton. The interclavicular and inter-articular cartilages at each end of the clavicle. The long costo-coracoid ligament.

It may not be out of place to briefly summarise the various stages the muscular system of the limbs of animals has passed through in its probable evolution to the highly differentiated condition we find in the highest mammals, including man.

In its simplest form it consists of a muscular sheet prolonged from the trunk to the distal end of the limb. This original sheet becomes divided into *proximal* and *distal* segments. Later, the mass divides into *layers*, which strata suffer longitudinal division into independent muscles. Any two of these may subsequently fuse to form a single muscle. The muscle may change its point of origin or insertion; more frequently this change affects the origin. This mode of change is conveniently termed *migration*. The extremities of the muscle may become metamorphosed into tendon, which tendon may, in certain cases, become divorced from the parent muscle, and remain in relation with a joint as

its ligament. Lastly, a muscle may abort, leaving no trace of its former existence, or be represented merely by fibrous tissue, re-appearing occasionally as an anomaly.

NERVES IN TENDON.

It seems to me that the view which would regard tendon as resulting from the metamorphosis of muscle receives some considerable support from the curious mode of nerve terminations in the tendons. Golgi and others have described certain long spindle-shaped bodies, composed apparently of modified connective tissue, into which one or more medullated nerve fibres end in small granular swellings. In others, structures something like the end-bulbs of the conjunctiva occur. Pacinian corpuscles have long been described in connection with the sheaths of tendons and ligaments. The general arrangement and termination of nerves in tendon strongly resemble those of muscle.

The whole question of the relation of muscles, tendons, and ligaments has a practical bearing, inasmuch as it affords an anatomical explanation of the knee-jerk phenomenon so familiar to schoolboys, which in the hands of the physician becomes an example of "philosophy in sport made science in earnest."

This paper must now be concluded. Doubtless independent workers will not agree with me on all the points discussed as to the nature of ligaments. Though I have made full use of the writings of other anatomists on questions of myology, yet I must add that the utility of their dissections, though of signal value in many points, has been very considerably narrowed, because the question of arthrology was neglected in the majority of cases. In the second paper I added a list of works with full acknowledgment of those which had served me well in this special study. All the subjects touched upon have been carefully considered and discussed without the bias of any preconceived opinion, and may possibly be nearer the truth in consequence. An abundant supply of fresh material for dissection has enabled me to verify all the facts detailed. I venture to publish them in the hope that others may be induced to investigate the subject still further. To me the inquiry has been a source of considerable interest, instruction, and pleasure.

The illustrations were drawn from my dissections by Mr Wynter and my brother; to them I am indebted for much help in this matter.

EXPLANATION OF PLATE XII.

Fig. 1. Showing the arrangement of the transversalis abdominis in a lizard (*Uromastix*). The dark-shaded portion is the true transversalis abdominis. The part near the vertebra corresponds to the retrahentes costarum. The lighter parts in mammals become diaphragm and subcostal muscles.

Fig. 2. Knee-joint of a tailed batrachian (*Menobrachius lateralis*). No fibro-cartilages or crucial ligaments.

Fig. 3. Knee-joint of frog (*Rana mugiens*, a tailless batrachian), with fibro-cartilages and crucial ligaments.

Fig. 4. Knee-joint of a lizard (*Teius teguexin*), with sesamoid bones in the fibro-cartilages.

Fig. 5. Knee-joint of a human foetus (third month), showing the three distinct synovial sacs.

Fig. 6. Knee-joint of a foetus at term; the three synovial sacs have fused, the ligamentum mucosum alone remaining. (The crucials and cartilages are not represented in this and fig. 5, so as to avoid complicating the figure.)

Fig. 7. Portion of the vertebral column of a skate, to show the interneural plates and the relation of the dorsal and ventral roots of the spinal nerves to the vertebral segments.

Fig. 8. A diagram of the spinal cord of an elasmobranch fish, showing the alternation of the dorsal and spinal nerve roots. (After Wiedersheim.)

Fig. 9. A drawing to represent the composite character of an intervertebral disc in the dorsal region of the spine of man.

Fig. 10. The glenoid fossa of the scapula, showing the relation of the biceps tendon, gleno-humeral, and coraco-humeral band to the capsular ligament and to one another.

SUPERNUMERARY CERVICO-DORSAL VERTEBRA-BEARING RIBS, WITH VERTEBRAL AND COSTAL ASYMMETRY; ABNORMAL ARTICULATION IN A STERNUM. By W. ARBUTHNOT LANE, M.S., F.R.C.S.,
Demonstrator of Anatomy to Guy's Hospital, and Assistant-Surgeon to the Hospital for Sick Children, Great Ormond Street.

IN the end of a paper I wrote in the Guy's Hospital Reports, 1883-84—"Cervical and Bicipital Ribs in Man"—I described the skeleton of a silvery gibbon (*Hyllobates leuciscus*, No. 65, Order Primates), in the Museum of the Royal College of Surgeons. It presented seven cervical vertebræ, and below these thirteen vertebræ-bearing ribs.

The first pair of ribs were but slightly curved, differing altogether in form from the first ribs in others of the same species. In front they were pointed, and were attached by slender fibro-cartilaginous bands to the manubrium, behind the facets for articulation with the clavicles. On the left side the second costal cartilage was attached to the manubrium in the position and after the manner of the normal first, and on the right side just a little below. The cartilages of the third ribs articulated on the same level with the sternum, at the junction of the manubrium and gladiolus. In that case, I was inclined to regard the upper pair of ribs as cervical ribs, and the supernumerary vertebra as an eighth cervical. At the same time, it suggested to me the possibility that many of the cases which are described as cervical ribs, fused cervical and first thoracic, or fusion of the upper two thoracic ribs, are frequently instances of a rib articulating with an eighth cervical, or fusion of this with a first thoracic rib; and that, owing to the absence of the rest of the skeleton, or to its imperfect examination, this fact has been overlooked. Against such a rib being regarded as cervical, it is not so very uncommon to find in man thirteen dorsal vertebræ, each bearing a rib; and in these cases there is no difficulty in regarding the lowest dorsal vertebra as the supernumerary one.

Instances of this kind have been described by Professor Struthers in the *Journal of Anatomy and Physiology*, vol. ix.—“On Variations of Vertebrae and Ribs in Man”—along with instances of supernumerary lumbar, sacral, and coccygeal vertebrae. I have failed to find any recorded case of supernumerary cervical vertebrae not bearing ribs. I recently observed in the dissecting-room a male subject, in which there were thirteen dorsal vertebrae-bearing ribs. These were typical dorsal vertebrae, and the ribs were normally arranged, eight articulating symmetrically with the sternum, the upper piece of which measured $1\frac{1}{2}$ inches, and the lower $4\frac{1}{4}$ inches. The outer span of the first ribs, which were symmetrical, was $2\frac{1}{4}$ inches. This subject presented many muscular abnormalities, among which were, on either side, chondro-epitrochlearis and three-headed biceps muscles. The case I will now describe is one of some importance, owing to the numerous deviations from the normal present in it.

It was a male subject. There were present seven cervical vertebrae, thirteen vertebrae-bearing ribs, five lumbar, and five sacral. There are thirteen ribs on either side. The first right rib resembles exactly in appearance the usual supernumerary cervical rib. It is movable, and extends forwards from its tubercle for three-quarters of an inch. Its head articulates with a prominence on the side of the body of the eighth vertebra. Till I had thoroughly dissected the subject, I considered it to be an instance of a cervical rib articulating with the seventh cervical, though I felt puzzled by the large size of the lower ribs and mesosternum. A dense fibrous band extended from its extremity to the upper margin of the rib below it. This band was merely a thickening in a fibro-muscular expansion, which was inserted into the whole upper border of this rib. Outside this was a layer of muscle fibre, apparently external intercostal muscle. Inside this was the anterior branch of the ninth nerve, which soon disappeared beneath the rib below. The greater part of the ninth nerve crossed the neck of the rib, and just before doing so it was joined by a large branch of the tenth spinal nerve.

The ganglia on the seventh, eighth, and ninth nerves were connected together by a greyish process. This appeared to contain no nerve fibre, and passed between the neck of the rib

transverse process, and through the foramen in the bifid transverse process of the seventh cervical.

The right second rib resembled in every particular a normal first rib. It articulated by its head with the side of the body of the ninth vertebra, and in front by a cartilage, corresponding in form and relations to the first costal, with the manubrium. The greatest span of this rib was $3\frac{1}{2}$ inches, its greatest breadth 1 inch. The measurements along its convexity and concavity were 7 inches and $4\frac{1}{2}$ inches respectively.

Anteriorly, the right third rib articulated by its cartilage, like the normal second, with the sternum at the junction of the first and second pieces. Its greatest breadth was half an inch. Below it six other ribs articulated with the sternum, making eight in all.

The right thirteenth rib was $4\frac{1}{2}$ inches long.

The left first rib articulated with the side of the body of the eighth vertebra, and with its transverse process.

In front of its tubercle the rib presented but a very slight horizontal curve, the shaft running almost directly forwards, being connected to the manubrium by its cartilage, in the usual position of the normal first cartilage.

The greatest span of this rib was 3 inches; its greatest breadth $\frac{5}{8}$ inch. The measurements along its convexity and concavity were 5 and $3\frac{1}{2}$ inches respectively. It differs very much from a normal first rib in appearance.

The left second rib resembles a normal second rib in form and direction. Its cartilage articulates with the sternum at the junction of the manubrium and gladiolus, one-third of an inch higher than the right third rib, owing to the lower margin of the manubrium being directed slightly obliquely upwards and to the left. Its convex measurement was 7, and its concave $5\frac{1}{2}$ inches.

The thirteenth rib is $4\frac{1}{2}$ inches long. On the whole, right costal cartilages articulate with the left half of the sternum, all below the first being on a level slightly higher than those on the right side.

Lying on the neck of the left first rib is a nerve formed by the greater part of the ninth and part of the tenth. The ganglia of the seventh, eighth, ninth, and tenth were connected, as were

those on the right side. The scalenus anticus was very small on both sides. On the right side it was perforated by the subclavian artery, and on the left by the artery and the cord formed by the ninth and tenth nerves. The right clavicle was 6 inches long; the left $5\frac{1}{2}$ inches. The omohyoids had only one fleshy belly each, which arose by an aponeurotic origin from the clavicle. There was no subclavius muscle present on either side.

The spinous processes presented numerous abnormalities. There was only one limb of bifurcation of the spine of the third cervical, viz., the left; and to it both the interspinous muscles were attached. The spinous processes of the fifth, sixth, seventh, and eighth vertebræ were not bifid. That of the seventh was rotated on itself through an angle of 45° . Its right transverse processes was bifid and perforated by a foramen, and the left was perforated but not bifid. The spines of the eighth and ninth resembled that of the ordinary vertebra prominens.

The left transverse process of the eighth vertebra is a quarter of an inch lower than the right; while that of the ninth is about one-third of an inch below its fellow. This is due to this transverse process being forced downwards and backwards, so forming a deeper and narrower groove between itself and the spinous processes than on the opposite side. It is evidently a compensatory change to allow of the greater crowding the ribs on this side. I have not seen this condition of vertebral asymmetry occurring congenitally before, though a similar change in form is produced by carrying heavy weights, or in ordinary lateral curvature. The left transverse process of the tenth and eleventh vertebræ are also slightly lower than those on the right, while the transverse processes of the twelfth are symmetrically arranged.

The spinous processes of the tenth, eleventh, and twelfth vertebræ were extremely short, merely forming stunted eminences at the junction of the laminae. The spines of the thirteenth and fourteenth gradually increase in size, and that of the fifteenth is almost normal in character.

The supraspinous ligament connecting the spines of the fifteenth, sixteenth, and seventeenth vertebræ is very dense and thick, and in it are two pieces of bone, the upper half an inch,

and the lower three-quarters of an inch, long. These do not appear to be connected in any way with the spinous process, but look like ossifications in the ligament.¹

The vertebral arteries enter the foramina in the transverse processes of the sixth cervical vertebra.

Looking at the whole description, I would regard the vertebra as a supernumerary cervical vertebra bearing ribs, and not as an instance of thirteen dorsal vertebræ bearing ribs, and in which the upper part of the chest was undeveloped. This is of course quite a matter of opinion, and I have published the full account, as it differs from any case I have yet come across.

The spinal column presented marked pressure changes, and was a good example of the second form of deformity which I described in the *Transactions of the Medico-Chirurgical Society* vol. lxxvii.—“Three Forms of Spinal Deformity.” The bodies of the cervical vertebra were more modified in form than they generally are, and the arthrodial articulations developed from the amphiarthrodial allow of much more movement than they usually do in this form of physiological deformity.

The next specimen is a sternum which I obtained from the body of an old woman in the dissecting-room. The manubrium and upper pair of pleurostea have united to form a single bone, which articulates with the remainder of the sternum by an amphiarthrodial articulation allowing of considerable movement. It is quite transverse in direction, and there is no synovial membrane present. The length of the upper piece of the sternum is $2\frac{7}{8}$ inches, and the first and second costal cartilages articulate with it, and on either side of the amphiarthrodial articulation are the third costal cartilages articulating partly with both bones.

Articulating also with the lower piece of the sternum, which measures $3\frac{1}{2}$ inches, are the cartilages of the four following ribs, and these are symmetrically arranged. The sternum is much narrower than usual. The ribs are about the average size. I have not seen this condition of sternal articulation, nor have I read of it as occurring in man.

¹ These I find sometimes in the greatly hypertrophied supraspinous ligament present in this region in this form of lumbar curve.

In a paper in the *Journal of Anatomy and Physiology*—"Sternal and Costal Asymmetry"—I suggested that the articulation usually present between the manubrium and sternum was due to the leverage action of the clavicle upon the first costal arch and manubrium; and these movements appear to be limited to man almost entirely.

In the orang-utans and in the gorillas it is not unusual for the manubrium to unite with one or more pleurostea of the gladiolus. In man it is by no means very uncommon to find the manubrium fused to the gladiolus. Why union should occur in some cases and not in others is difficult to understand. Maisonnaue ("Luxations du Sternum," *Archiv. Gen. de Médecin*, ser. iii. vol. xiv.) ascribed it to changes taking place in old age; but I have found it as frequently in the vigorous adult as in the old subject.

I have thoroughly examined many chests in which this fusion of the sternal pieces had taken place, but I have failed to find any circumstances which is invariably present which can be regarded as a determining influence or cause. It seems to occur more frequently among men than women. It is present in cases in which the upper part of the chest is relatively large, as well as where it is relatively small. It is also present in men who had performed much hard labour, as well as in women.

As a very large proportion of sterna possess an articulation, one can only conclude that its absence is due to an unusually rapid growth and fusion of the pleurostea before the causes determining the formation of an articulation have had time to act, and that in the sternum I have just described, though the manubrium and the upper pair of pleurostea had united, these causes were sufficient to determine the formation of an articulation, and so to associate intimately in the movements of the clavicle the second as well as the first costal arch. I had hoped that this specimen would have thrown some light on the causes which determine the joint formation.

CERVICAL RIB IN FEMALE SUBJECT.

The vertebral formula is normal.

The cervical rib, which is on the right side, is a fixed one.

From its tubercle to its head it measures 1 inch, and from the tubercle to the anterior extremity its length is $1\frac{1}{2}$ inches. Its head is connected by fibrous tissue and ligaments to the adjoining margins of the sixth and seventh cervical vertebræ and intervertebral substance, it being, however, bound more intimately to the seventh than to the sixth vertebra.

This attachment of the head differs from what I have previously seen, as it is usually attached to the body of the seventh vertebra, midway between its upper and lower borders.

The neck is separated from the transverse process by a space, through which pass an artery and vein.

The tubercle presents a large facet, connected to the transverse process by ligamentous tissue chiefly, but in its outer part by bone, so rendering the rib a fixed one.

The shaft of the rib presents near its extremity two grooves, the anterior being well marked and occupied by the subclavian artery. The posterior one is grooved by the cord formed by the eighth cervical and first dorsal nerve.

From the extremity and lower margin of the rib a fibro-muscular layer is attached to the upper margin of the first thoracic rib, and into the outer half-inch of its cartilage. It is very fibrous in its inner portion, forming in its inner margin a firm tendinous cord.

Behind this expansion, and intimately connected with it, is the dome of the pleura.

The scalenus anticus is small, but arises normally from the tubercles. Below it spreads out and forms a tendinous expansion, which is inserted into the outer part of the margin of the tendinous prolongation of the cervical rib.

The scalenus medius is inserted partly into the cervical and partly into the first thoracic rib.

The eighth cervical nerve, before being joined by the first dorsal, gives off an anterior branch, which runs in the space below the cervical rib, then on beneath the fibro-muscular expansion, and then beneath the first thoracic rib, perforating the muscles in the interspace below it, and becoming cutaneous. On the left side the cervical rib consists of a head which is connected by intervening ligament to the upper margin of the seventh cervical, and of a neck which is separated from the

transverse process by a foramen-transmitting vessel. Outside this it is continuous with a large transverse process, and only projects slightly from it, forming a blunt extremity. There is arising from it a fibro-muscular expansion, exactly similar but smaller than that on the opposite side. The subclavian artery lies on the free margin of this expansion, and not on the rib below.

The scalenus anticus is inserted as on the right side, the inner limit of its expansion reaching the upper margin of the first rib. It is split by the artery. The arrangement of the nerves is the same as on the opposite side.

The first thoracic ribs articulate equally with the seventh cervical and first dorsal vertebræ. They are more oblique than usual, resembling rather normal second ribs in appearance. Neither is grooved by the subclavian artery. The outer span measures $2\frac{7}{8}$ inches.

The eleventh rib measures about 8 inches, the left being a little longer than the right.

The twelfth rib is fixed on the right side, and measures 2 inches, and on the left side it is absent.

The manubrium is very broad, its broadest part measuring $2\frac{1}{2}$ inches. It is $1\frac{3}{4}$ inches long. The gladiolus is $3\frac{3}{4}$ inches long. Seven cartilages articulate with the sternum.

In this instance, though the cervical rib is larger on the right side, the twelfth rib is alone present on the same side. The subclavian arteries appeared to lie in a plane posterior to that usually occupied by them. Though the manubrium is not much longer than usual, it is certainly considerably broader. I have described this case in detail, as it presents some deviations in character from those I have already examined.

SOME POINTS IN THE HISTOLOGY OF THE MEDULLA
OBLONGATA, PONS VAROLII, AND CEREBELLUM.
By W. AINSLIE HOLLIS, M.D. Cantab., Brighton. Part V.
(PLATE XIII.)

The Olivary Bodies.—The longitudinal reticular fibres of the medulla, in passing on the inner or central side of the dentate bodies of the olivary nuclei, appear to be closely associated with the proper fibres of the siliquæ, and in this way these ganglionic zones may be indirectly connected with the spinal cord. The general arrangement and trend of the fibres passing to and from the capsules and central nuclei make it, however, more probable that these bodies belong to the cephalic than to the rachidian neural system. For instance, the hilus, with its associated hypoglossal and other nerve fibres, forms a bond of union between the intra-olivary tissues and the grey vesicular floor of the fourth ventricle (*cf. Van der Kolk, On the Medulla Oblongata*, N.S.S., p. 143); but this portion of the central grey substance does not run uninterruptedly into the vesicular columns of the cord, as I have elsewhere shown (*Jour. of Anat. and Phys.*, vol. xviii. p. 412). On the dorso-cephalic aspect of each olive the fibres of the siliqua pass outwards through interruptions in the dentate zone. A large contingent of these fibres passes dorsally towards the cerebrum, some distance below the grey ventricular floor, accompanying the longitudinal reticular fibres of this region, and also the dorsal pyramidal branch to be subsequently described. Possibly some lateral fibres from the cephalic extremities of the siliquæ join others, which curve backwards and upwards to the middle peduncle, and there become associated with the cerebellar dentate body on either side; for I have traced a bundle of fibres passing in the direction mentioned. This arrangement produces a complicated decussation of nerve-fibres on either side of the pons. Along the dorsal aspect there are three principal involutions of the dentate zone in each olive, excluding those at the cephalic and caudal extremities respectively. The general direction of these involutions is backwards and downwards (fig. 2, numerals). Anteriorly, there are several

breaks in the dentate body through which fibres pass upwards to the pyramidal trunks from the central nuclei. The folds of grey substance of the olive in a bilateral longitudinal section have a general direction upwards and outwards (fig. 1, *ol, ol*). The whole olive in such a section seems apparently to be divided by deep involutions of synectic tissue into three or more separate nuclei, as seen in the same figure, which was copied from a photograph. These divisions, however, are only apparent, and not actual, as other sections of the olives clearly demonstrate. On the inner or central aspect a narrow band of vesicular substance, containing cell-clusters similar in form to those of the dentate zone, although possibly somewhat larger, represents on either side of the medulla a supplementary olivary nucleus (the pyramidal nucleus of Stilling). This vesicular zone passes downwards to the caudal extremity of its respective olive, and then, curving somewhat outwards, terminates about a line below that body (fig. 1, *ol'*). It is surrounded by loose synectic tissue, and is largely supplied with blood-vessels. Of the nerves associated with the olives, the restiform-arcuate fibres are the most numerous, and probably the most important (fig. 4, *r, r, ar, ar*). In passing through the dentate zone, the curved restiform fibres become more sinuous in outline, frequently split up into several smaller bundles, which subsequently reunite again, or widen out, forming a brush-like extremity of terminal fibrils, shown in the figure, which is copied in outline from a photograph. On the inner or central side the restiform fibres unite with the arcuate septa of the raphé (*ar, ar*). These septa (or fibres, as they are erroneously called) are visible in transverse sections of the medulla as short parallel bands of synectic tissue, containing nerve fibres, which in some instances cross the raphé. The connection between the curved restiform fibres and the septa is curious. Each restiform fibre on approaching the latter is split into two or more bundles of fibrils, to be connected separately with neighbouring arcuate septa. Furthermore, each arcuate septum is associated with two or more adjacent restiform fibres, an arrangement readily observable in the figure. This description only applies to transverse sections of the medulla; for in reality each arcuate septum probably collects fibrils from a large number of adjacent restiform fibres. It is only in this manner

that these fibres could fill as they do the lengthened interstices between the longitudinal reticular fibres which here represent the arcuate septa (fig. 5). The hypoglossal nerve-trunks pass usually across the dentate bodies at angles nearly approaching right angles. This structural peculiarity precludes in most instances the idea of any direct communication between them. I have, however, occasionally traced a few nerve-fibrils from the main trunk to pass along with the restiform fibres dorsally towards that body. Many of the apparent nerve offsets from the hypoglossal fibres are really traversing restiform fibres (fig. 4, *hy*).

In certain cases the brush-like terminal fibrils of the dentate zone seem to pass outwards with a hypoglossal trunk. It may be that this arrangement implies, as Van der Kolk surmised, a close physiological relationship between the hypoglossal nerves and the olivary nuclei. He, however, based his argument on the assumed connection between the hypoglossal nuclei and the olives, and not from the anatomical data I have here mentioned.

The Pyramids in the Pons Varolii.—The main pyramidal trunk, as I have above stated, bifurcates on either side at the apex of the olivary nucleus (fig. 3, *pt*). Of the two branches so formed, the dorsal, in conjunction with fibres from the olivary capsule (fig. 3, *dp*, *so*), passes immediately behind the transverse fibres of the trapezium and the deep fibres of the middle cerebellar crus (fig. 6, *dp*). This branch runs for a considerable distance in close proximity, but somewhat deeper than the main body of pontile reticular fibres, a continuation of the longitudinal fibres of the medulla. About on a level with the superior foveæ, the dorsal pyramidal branch, with its mixed capsular and possibly reticular fibres, again bifurcates on either side of the pons. One of these branches, curving closely round the transverse fibres of the trapezium, and surrounded by a sheath of grey synectic tissue, flattens out as it approaches the cerebrum, and forms a horizontal band of longitudinal fibres, separating the dorsal from the ventral elements of the pons. This flattened band of longitudinal fibres, which with ordinary care can be readily traced hindwards in the course I have described, constitutes the *fillet* of anatomists.

The second or posterior ramulus of the dorsal pyramidal branch soon loses most of its traces of separate identity amongst the longitudinal reticular fibres of this portion of the pons. It is possible that the posterior longitudinal bundle of Flechsig may be a continuation of this branch towards the crura cerebri. I have been, however, unable satisfactorily to trace this connection owing to the reason above given.

At the apices of the olives two well-marked involutions of pia mater—one on either side—mark the cephalic termination of the medulla oblongata.

The general arrangement of the central layers of the pontile fibres (fig. 7), well shown in the specimen whence this figure was taken, may assist somewhat in rendering clear this attempt to explain the course of the pyramidal fibres in the pons Varolii.

At the point *p* in the figure, but somewhat external to this section, the fibres of the main pyramidal trunk bifurcate, some passing ventrally *vp*, others dorsally in the direction, but external to *ar*, *ar*. At a point on a level with the dotted line *pm*, the dorsal pyramidal branch again bifurcates.

The ventral branch of the great pyramidal trunk passes between the transverse crural fibres, which constitute the bulk of the ventral portion of the pons. It is much larger than the dorsal segment, and passes somewhat more superficially than the latter. It speedily splits into several smaller branches, which reunite towards the crusta of the cerebral peduncles (figs. 3 and 6, *vp*; fig. 7, *p*, *vp*).

The Trapezium.—This portion of the crura cerebelli in a longitudinal section appears as a series of flattened parallel bands of synectic tissue traversed anteriorly at comparatively wide intervals by connecting filaments of the same tissue. The meshes surround the transverse peduncular fibres. Towards the caudal extremity of the trapezium this stroma becomes more delicate and the reticulations smaller (figs. 3 and 7, *tr*).

The grey substance of which the above structure is formed contains numerous small pyriform cells within it. Both it and the grey sheath of the lemniscus, identified above as the second dorsal pyramidal branch, are together traceable to the substantia nigra of the crura cerebri. With the exceptions above alluded to, the whole ventral section of the pons appears to be more or

less completely shut off from the rest of the nervous system by deep pia matral involutions.

The superficial transverse fibres of the pons Varolii are divided from the deeper layers of that body in longitudinal sections by a well-marked broad band of grey synectic tissue, which at its free edge has numerous projections terminating in delicate reticular filaments (figs. 3, *vtf*, and 7). The transverse fibres pass between the reticulations. The grey substance also originates in the crura cerebri, and owing to deep pia matral involutions has no apparent connection with the spinal system.

The Longitudinal Reticular Fibres and Arcuate Septa.—The longitudinal fibres on the inner (central) aspect of the olives in their passage upwards through the pons pass around the caudal extremity of the trapezium and along its dorsal surface, where they join other reticular fibres of this region (fig. 7, *ar*, *ar*).

In conclusion, it may perhaps be advisable to give a short description of the method adopted by me in preparing the microphotographs for these researches. The best results have been obtained by oblique illumination when an argand oil burner and a plano-convex lens were used. By these means variations in tissue formation, scarcely observable otherwise, either micro- or macroscopically, become clearly perceptible in the negative. Owing to the varying refractive indices of the synectic and other tissues of the central nerve substance, these differences are strikingly seen in the subsequent dry plate photograph if the manipulation of the oblique light has been judiciously managed. Aniline dyes, as a rule, by staining the nerve fibres more readily than the grey synectic tissue, are most useful for some specimens; whilst picrocarmine, which differentiates the nerve ganglia and grey synectic tissue by their colours, must be employed in other cases. In the accompanying Plate figs. 1 and 5 are facsimiles of photographs. Fig. 3 is drawn in outline, and partly shaded from one taken by oblique light. The principal nerve fibres passing amid the dentate body of the olive (in fig. 4), have also been drawn in facsimile. Fig. 6 represents a specimen stained by Judson's scarlet aniline dye. In it the dorsal pyramidal branch over the trapezium is well shown, whereas, in a specimen stained by picrocarmine, this structure is scarcely visible in transverse section.

EXPLANATION OF PLATE XIII.

Fig. 1. Longitudinal bilateral section of right olive (from a photograph). Human adult. *ol, ol*, Corpus dentatum of olive; *ol'*, accessory olive, with blood-vessels passing through the loose synectic tissue adjacent to it; *pm*, pia matral involution.

Fig. 2. Longitudinal (antero-posterior) section through centre of olive, showing the principal involutions (1, 2, 3) of dentate zone along posterior (dorsal) border. Human adult. *ce*, Cephalic; *ca*, caudal extremity; *ao*, accessory olive.

Fig. 3. Longitudinal (antero-posterior) section of bifurcation of pyramidal trunk (outline drawn from a photograph). Human adult. *pt*, Right pyramidal trunk; *dp*, dorsal; *vp, vp*, ventral branches; *so*, siliqua olivæ; *pm*, pia matral septum; *ol*, olivary body; *tr*, trapezium; *vtf*, superficial transverse fibres of pons.

Fig. 4. Semi-diagrammatic figure of the nerve-fibres passing amid the olivary bodies (drawn in outline from a photograph). *o*, A portion of dentate zone of olive; *ao*, accessory olive; *hy*, hypoglossal nerve-fibres; *rr*, restiform; *ar, ar*, arcuate fibres (leading to raphé).

Fig. 5. Longitudinal antero-posterior section of arcuate septa and the longitudinal reticular fibres on the central side of olivary body (from a photograph). The dark interspaces are the arcuate septa. *v*, A vessel.

Fig. 6. Transverse section of the pons Varolii (right side) near the centre of middle cerebellar crus (*cc*). Human. *dp*, Dorsal pyramidal branch; *vp, vp*, ventral pyramidal branch; *tr*, trapezium; *tf*, superficial transverse fibres; *iv.*, floor of fourth ventricle.

Fig. 7. Longitudinal (antero-posterior) section of pons Varolii and upper part of medulla, internal to the right olive. Man. *ar, ar*, Longitudinal reticular fibres; *p*, pyramidal trunk; *vp*, ventral branches; *sf*, superficial transverse fibres; *tr*, trapezium; *pm*, pia mater; *iv., iv.*, grey floor of fourth ventricle.

Figs. 1, 2, and 3 are magnified about 6 × 6

Figs. 4 and 5 are magnified about 40 × 40.

THE EXTERNAL AUDITORY MEATUS IN THE CHILD.

By J. SYMINGTON, M.B., F.R.C.S.E., *Lecturer on Anatomy, Edinburgh.* (PLATE XIV.)

IN this paper I propose to give the results obtained from a study of a series of frozen sections of the external auditory meatus in the child, and to compare them with the various views held with regard to its anatomy.

An examination of the literature on this subject will show that this method of investigation has been almost entirely neglected. The only illustrations of frozen sections that I have succeeded in finding are a few somewhat diagrammatic representations of sections of the meatus in the new-born infant.

For facility of comparison most of my sections were made in the same direction, viz., transverse vertical, or coronal. The meatus was generally divided nearer the anterior wall than the posterior, and in all of them the posterior part of the section was traced, so that the specimens in the plate are represented as seen from the front. I have also made a few sagittal and horizontal sections. All the drawings of sections are life size, and made from tracings taken while the parts were frozen. To check and supplement the results obtained from the frozen sections, a number of ears were dissected in the ordinary way, and the skulls of several children were macerated.

Length of the Meatus.—In estimating the length of the meatus no difficulty is experienced in defining its inner extremity, for this is clearly marked by the membrana tympani; but as this membrane passes from above downwards and inwards, and from behind forwards and inwards, none of the walls extend to within the same distance from the mesial plane of the body. With regard to its external boundary, this is not so well defined; and, according to Gruber,¹ the very various estimates of the length of the meatus are mainly to be attributed to a want of agreement as to its limits externally. Some anatomists, Meckel for example, have even included the tragus in their measurements

¹ *Lehrbuch der Ohrenheilkunde mit besonderer Rücksicht auf Anatomie und Physiologie*, Wien, 1870.

of the walls of the meatus. The only part of the outer end of the meatus which can naturally be distinguished from the concha of the pinna is its posterior wall, for this turns abruptly backwards, while the other walls pass outwards into the pinna without any distinct line of demarcation. The majority of authorities now agree with von Tröltsch in taking as the external boundary of the meatus a sagittal plane passing through the outer end of its posterior wall. The most careful and exact measurements of the length of the meatus are those of von Tröltsch. He gives 24 mm. as its average length in the adult, its anterior wall being 27 mm., lower 26, posterior 22, and upper 21. I have not been able to find any precise statements as to its length in the child; and, indeed, in almost all works on the anatomy of the ear there are no allusions to this point. The subject is, however, referred to in Quain's *Anatomy*, 9th edition, vol. xi. page 434, as follows:—"The auditory passage is very short and rudimentary in the infant, for the osseous part begins to grow out of the temporal bone only after birth, and thus the internal and middle ears are much nearer to the surface than in the adult."

As the walls of the meatus in the infant are soft and yielding, it is obvious that care must be exercised in measuring its length not to stretch or compress it in any way. The length of other passages—for instance, the vagina—has been greatly exaggerated by not attending to this rule. To avoid such sources of fallacy I have estimated its length from frozen sections, and below will be found a table of a series of measurements of the roof and floor of the meatus obtained by this method.

No	Age.	Length of Floor.	Length of Roof.
1	Fœtus, 7 months old, . . .	16 mm.	10 mm.
2	" 9 " . . .	20 "	15 "
3	" 9 " . . .	20 "	15 "
4	" 9 " . . .	19 "	15 "
5	Child, 2 " . . .	17 "	13 "
6	" 6 " . . .	19 "	14 "
7	" 12 " . . .	20 "	15 "
8	" 2 years old . . .	22 "	16 "
9	" 5 " . . .	23 "	16 "
10	" 6 " . . .	24 "	17 "

If we compare the above with the length in the adult, as given by von Tröltzsch, it will be evident that the meatus instead of being shorter is relatively longer than in the adult. Thus, in the new-born child the floor is 20 mm., in the adult it is 26 mm. or little more than one-fourth longer. As one would naturally expect from this the meatus increases very slowly in length after birth; indeed, from my cases, it would appear at first to diminish. My specimens are too few to warrant any definite conclusions; but I am disposed to think that the opening up of the meatus, which occurs after birth, is accompanied by some slight diminution in its length. Henle states that the estimates of the length of the meatus vary from 22 mm. to 42 mm. These discrepancies have arisen from a want of agreement as to its external boundary (Gruber), and also probably from the method of examination. My results show only very slight individual variations.

The practical importance of an accurate knowledge of the length of the meatus needs scarcely to be insisted upon; but these measurements are also of interest in connection with the relative size in the child and adult of other parts of the ear. It is well known that the middle and internal ears are nearly as large at birth as in the adult, and the same would appear to be the case with the external ear, so far as the length of the meatus is concerned.

Lumen of the Meatus.—In the foetus the meatus is closed, its lower wall being in contact internally with the membrana tympani, and external to it with the superior wall. Towards the end of foetal life these become separated by an accumulation of epithelium or vernix caseosa in the meatus. This is first found at the inner end of the meatus, between the floor and the membrana tympani. The coronal section of the meatus of a nine months' foetus, seen in Plate XIV. fig. 1, shows only slight separation of the walls, but in another subject at the same age the meatus was rather more opened up. In both cases respiration had not occurred.

At birth the walls of the meatus are either in contact or the cavity is filled with vernix caseosa, so that a child is born with its ears practically closed.

According to Kussmaul,¹ the most discordant sounds made near a new-born child, when awake, do not apparently disturb it. I am not aware of any observations as to how soon after birth, or by what agencies, the meatus becomes a distinct air passage. In an infant six days old I found the walls of the meatus more separated than is normally the case with a new-born child, but its cavity was nearly full of detached epithelium, &c. In a child, aged two months (see Plate XIV. fig. 2), the meatus was patent and contained air. The lumen of the meatus would appear to gradually increase in size after birth, but so slowly that it is relatively narrow in the infant as compared with its length.

By the growth of the tympanic bone the osseous meatus is usually formed between the ages of twelve and fifteen months. From an examination of several specimens about this age, kindly lent me by Professor Turner, and from others in my own possession, I found that the osseous meatus measured from above downwards and backwards on an average 6 to 7 mm. In the adult it is generally from 8 to 9 mm.

Walls of the Meatus.—Most of the standard works on anatomy give a very imperfect description of the structure of the walls of the meatus in the child. They state that in the adult the meatus consists of an osseous and a cartilaginous portion, while in the new-born infant there is no osseous meatus; and the reader is too often led to infer that at that period the meatus is entirely cartilaginous. Indeed, Tillaux in his *Traité d'Anatomie Topographique*, 3rd edition, 1882, page 99, says:—"Chez l'enfant nouveau-né le conduit auditif est donc exclusivement fibro-cartilagineux." It was shown, however, more than thirty years ago by von Tröltsch that this idea is erroneous, for, in the new-born child as in the adult, the outer part only is cartilaginous, and in the new-born infant the future osseous portion is represented by fibrous tissue into which ossification extends to form the greater part of the walls of the osseous meatus. This membrane, which might be called the fibrous or membranous tympanic plate, is shown in section in the floor of the meatus in Plate XIV. figs. 1, 2, 3, and 4. At birth it is thin; but it be-

¹ *Untersuchungen über das Seelenleben der neugeborenen Menschen*, Leipzig, 1859.

comes thicker and firmer in a few months. Fig. 6, a sagittal section of the meatus in a child four months' old, made 9 mm., external to the inner end of the floor of the meatus, exhibits its relation to the anterior and inferior walls of the meatus. Julius Böke¹ maintains that this structure, described as membrane by Tröltsch, really consists of cartilage composed of fibres with scattered cells. In the account of the minute anatomy of the external ear by J. Kessel in Stricker's *Histology*, there is no reference to it. I have satisfied myself by microscopic examination that it is compact fibrous tissue and not cartilage.

It is generally taught that at birth there is no osseous meatus. This scarcely conveys a correct idea of the condition of walls of the meatus at this period, for there is then an osseous roof and posterior wall. The roof is shown in the coronal section of the meatus of the new-born child in Plate XIV. fig. 1, and its gradual increase is seen in figs. 2 to 5. The sagittal section in fig. 6, from a child aged 4 months, was made just internal to the cartilaginous portion. It shows the bony posterior and superior walls, and the anterior and inferior fibrous walls.

The formation of the tympanic portion of the osseous meatus has been investigated by Humphry, von Tröltsch, Bürkner, and Zuckerkandl. The latter is quoted by Politzer² as describing the formation of the tympanic bone as commencing by the rapid growth of the anterior and posterior tubercles found on the tympanic ring of the new-born child. The lower part of the tympanic ring grows out more slowly, and the two tubercles uniting a foramen is left in the tympanic bone which sometimes remains throughout life. An essentially similar description was given by Humphry in his *Treatise on the Human Skeleton* published in 1858, and in plate xvi. of the same work there are several drawings illustrating this process. After the union of the two processes of the tympanic bone, a distinct osseous external auditory meatus exists. Von Tröltsch gives a drawing of a temporal bone of a child about three years old, in which a gap open to the outer side is shown in the tympanic bone. The rate of ossification of the tympanic bones varies somewhat, but as a rule the tubercles of the tympanic ring unite at or soon after the end of the first year.

¹ *Virchow's Archiv.*, Bd. xxix., 1864. ² *Lehrbuch der Ohrenheilkunde*, 1878.

EXPLANATION OF PLATE XIV.

Fig. 1. Coronal section of left ear of a nine months' fœtus.

Fig. 2. Coronal section of right ear of a child two months old.

Fig. 3. Coronal section of left ear of a child six months old.

Fig. 4. Coronal section of right ear of a child twelve months old.

Fig. 5. Coronal section of right ear of a child five years old.

In figs. 1 to 5: *a*, tympanic bone; *b*, fibrous tympanic plate; *c*, fibro-cartilage.

Fig. 6. Sagittal section of left ear of a child four months old; *t*, tympanic cavity; *m*, external auditory meatus; *b*, fibrous tympanic plate; *i*, inferior maxilla.

ON THE RELATIONS OF THE LARYNX AND TRACHEA
TO THE VERTEBRAL COLUMN IN THE FÆTUS
AND CHILD. By J. SYMINGTON, M.B., F.R.C.S.E., *Lecturer
on Anatomy, Edinburgh.*

ALTHOUGH various attempts have been made to settle the vexed question of the relative size of the larynx at different periods of life, they have been practically confined to measurements of the larynx after its removal from the body; and while it is well known that the larynx occupies a relatively high position in the neck of the infant as compared with the adult, no attempt has hitherto been made by an examination of the organ *in situ* to determine its precise relations, at different ages, to the vertebral column.

In the adult, with the head erect, the boundary between the larynx and trachea corresponds to the lower border of the sixth cervical vertebra. The tip of the epiglottis reaches up to the lower border of the third cervical, or probably a little higher in the male, and the trachea extends down to the fourth dorsal. These are the relations according to the drawings given by Braune,¹ Rüdinger,² and Luschka.³

In the new-born child both the larynx and trachea terminate at higher points in relation to the vertebral column than in the adult; but I have not succeeded in finding any definite statements as to their precise position. As a rule, the larynx ends opposite the middle of the fourth cervical and the trachea bifurcates at the level of the lower border of the second dorsal. In a drawing of a frozen section of a new-born child, Rüdinger⁴ shows the larynx extending down to the upper border of the fourth cervical. He does not clearly indicate the bifurcation of the trachea, but I have found it as stated above. Ribemont,⁵ in a rather rough drawing, indicates the lower border of the cricoid as being opposite the middle of the fourth cervical.

¹ *Topographisch-anatomischer Atlas*, plates i. and ii.

² *Topographisch-chirurgische Anatomie des Menschen*, Zweite Abtheilung, plate vii.

³ *Der Kehlkopf*, plate iv.

⁴ *Op. cit.*, plate ii.

⁵ *Recherches sur l'anatomie topographique du fœtus*, plate vii.

It is evident from these facts that the lower limits of the larynx and trachea must undergo a considerable descent in relation to the vertebral column between infancy and adult life, and the question arises as to when and how this occurs.

In a former paper,¹ I showed that in a child aged two years, with the head fully extended as in the operation for tracheotomy, the lower border of the cricoid extended to the lower border of the fourth cervical, and the trachea terminated at the lower border of the first dorsal. Since then, I have, as opportunities occurred, continued the investigation of this subject, and in the following table will be found some of the results I have obtained. All the cases given in the table are from specimens in my possession, and in all of them the entire trunk was frozen.

Table showing the position of the Larynx and Trachea in relation to the Vertebral Column.

Age.	Sex.	Upper end of Epiglottis.	Lower border of Cricoid.	Bifurcation of Trachea.	Position of Head.
Fœtus about 4 months.		...	Upper border of fourth cervical.	...	Erect.
" 6 "	M.	Below atlas.	Middle of fourth cervical.	Second dorsal.	Slightly flexed.
" 7 "	F.	Upper border of atlas.	Upper border of fourth cervical.	Second dorsal.	Erect.
" 7 "	F.	Lower border of atlas.	Middle of fourth cervical.	Middle of third dorsal.	Erect.
" 9 "	M.	Between body and odontoid process of axis.	Middle of fifth cervical.	Middle of third dorsal.	Flexed.
Child aged 2½ months.	M.	Lower border of atlas.	Lower border of fourth cervical.	Middle of third dorsal.	Erect.
" 4 "	M.	Lower border of atlas.	Upper border of fifth cervical.	Middle of third dorsal.	Slightly flexed.
" 6 "	F.	Little below atlas.	Upper border of fifth cervical.	Lower border of third dorsal.	Erect.
" 8 "	M.	Lower border of atlas.	Middle of disc between third and fourth cervical.	Middle of second dorsal.	Fully extended.
" 12 "	F.	Little below atlas.	Upper border of fifth cervical.	Lower border of third cervical.	Erect.
" 1 year and 10 months.	F.	...	Upper border of sixth cervical.	Lower border of fourth cervical.	Acutely flexed.
" 2 years and 2 months.	F.	Little below atlas.	Upper border of fifth cervical.	Upper border of fourth dorsal.	Extended.
" 5 years.	M.	Lower border of axis.	Upper border of sixth cervical.	Lower border of fourth dorsal.	Erect.
" 6 years.	M.	Lower border of axis.	Lower border of fifth cervical.	Middle of fourth dorsal.	Erect.
" 13 years.	F.	Middle of third cervical.	Upper border of seventh cervical.	Lower border of fourth dorsal.	Flexed.

It will be noticed that in this table the position of the head has been mentioned in each case. This is necessary, for the

¹ "On the Anatomical Relations of the Trachea in the Child," *Edinburgh Medical Journal*, April 1881.

larynx moves up and down in front of the vertebral column during extension and flexion of the head. In order to determine the changes in its situation resulting from alterations in the position of the head, I froze two children of almost exactly the same height, one a little under, and the other a little over, two years. In the one case I depressed the head so that the chin came in contact with the front of the neck, in the other the head was thrown well back. In the former an examination of the section showed that the relative position of certain structures had been considerably altered. The anterior surfaces of the bodies of the lower two cervical and upper two dorsal vertebræ formed a slight convexity, but above this there was a concavity, and here the intervertebral discs were much compressed. The soft palate had been pushed up against the roof of the pharynx, and the tip of the epiglottis was just behind the soft palate. The thyroid cartilage was behind the hyoid bone, their lower borders were at about the same level; but the upper border of the thyroid was 3 mm. above the hyoid. Contrary to what one might have expected, the distance in front, between the cricoid and thyroid, was a little longer than normal. Part of the trachea was compressed, and its lumen almost obliterated by the pressure of the chin. The lower border of the cricoid was at the level of the upper border of the sixth cervical. In the specimen with the head extended, the cervical curve of the spine was well marked. The hyoid was more above and in front of the thyroid than is usually the case, and the cricoid was a vertebra higher than in the body with the head acutely flexed.

A comparison of the two specimens demonstrated that the flexion of the head was chiefly marked by the descent of the hyoid bone in front of the thyroid cartilage, and that, compared with the extensive movement of the head, the downward displacement of the larynx in relation to the vertebral column was comparatively slight, amounting only to about one vertebra and intervertebral disc.

In the specimen in which the head was flexed, the trachea bifurcated opposite the lower border of the fourth dorsal, in the other one opposite the upper border of the third dorsal. In both cases, therefore, it was situated in front of the same number of vertebræ, viz., six; but in the former case the trachea was 4·5

cm. in length, and the intervertebral discs in the corresponding part of the vertebral column were compressed; in the latter the length of the trachea was 5·7 cm., and the anterior part of the intervertebral discs was stretched. These sections confirm the statement of Braune, that in the movement of the head from the flexed to the extended position the trachea is considerably increased in length, and they would also seem to show that its point of termination is raised.

The lower border of the cricoid cartilage forms a well-defined landmark, by means of which we can easily determine the relation of the lower border of the larynx to the vertebral column. An examination of the table shows a tolerably regular and gradual descent of the cricoid in relation to the vertebral column. Thus, with the head erect, it was opposite the upper border of the fourth cervical in a young foetus; by the end of the first year it was down to the fifth, and by the fifth year it reached to the level of the upper border of the sixth cervical. Had the head been erect in the girl aged 13, I think it would have corresponded to about the middle of the sixth cervical. These results show that the altered position of the lower border of the larynx, in relation to the vertebral column, has no connection with the special increase in the size of the larynx, which occurs in the male at puberty.

The question now arises, Is this downward movement of the lower border of the larynx the result of the larynx growing more rapidly than the cervical part of the vertebral column, or is it due to a displacement downwards of the whole larynx? In order to answer this question, it is necessary to ascertain the position of the upper end of the larynx at different periods of life. For this purpose, I have endeavoured to determine the level of the tip of the epiglottis, although it must be confessed that this cannot be settled as satisfactorily as might be wished. It is, however, evident, from a study of the results given in the table, that it, like the cricoid, undergoes a considerable and tolerably gradual descent in relation to the vertebral column from foetal to adult life. Rüdinger¹ represents the tip of the epiglottis at the level of the middle of the anterior arch of the atlas in a new-born child, and this appears to be about its usual position at that age. In an adult female he² shows it opposite

¹ *Op. cit.*, plate ii.

² *Ibid.*, plate vii.

the disc between the third and fourth cervical, and it occupies practically the same level in two sections of females given by Braune. In the section of an adult male by Braune, it is a little above the middle of the third cervical.

We may fairly take the usual position of the larynx in relation to the vertebral column to be, in the new-born child, from the lower border of the atlas to the middle of the fourth cervical vertebra, in the adult, from the middle of the third cervical to the lower border of the sixth cervical.

In Braune's atlas,¹ plate i., a life-size drawing of a mesial section of a man aged 21, the vertical extent of the larynx, from the tip of the epiglottis to the lower border of the cricoid, amounts to 7.2 cm.; in the same subject, the distance from the lower border of the anterior arch of the atlas to the middle of the fourth cervical is 6.8 cm. In plate ii., a similar section in a female subject, the length of the larynx was 5.5 cm., and the distance between the above-mentioned points on the spine is 5.2 cm. The drawing in plate vii. of Rüdinger's work² represents a mesial section of an adult female. The drawing is not life-size, but has been reduced by photography. In it we find the vertical extent of the larynx equal to the distance from the atlas to the middle of the fourth cervical. We have obtained practically similar results by measurements in children aged 6 months, 12 months, 5 years, and 6 years.

From these measurements it is apparent that if the adult larynx were placed in front of the vertebral column, so that the tip of the epiglottis was on a level with the lower border of the atlas, the cricoid cartilage would not extend beyond the lower border of the fourth cervical.

The larynx, therefore, does not increase in vertical extent faster than the cervical part of the spinal column, and, consequently, the high position of the larynx in the neck of the child, as compared with the adult, cannot be due, as often stated, to its relatively small size.

It attains its low position in the adult by a downward movement of the whole larynx; and I am inclined to the belief that this is almost, if not entirely, caused by the growth of the facial portion of the skull. The relatively small size of the face as

¹ *Op. cit.*

² *Op. cit.*

compared with the cranium in the child has been investigated by Froriep.¹ He estimates the relative size of the face to the cranium as 1 to 8 in the new-born child, 1 to 6 at two years, 1 to 4 at five years, 1 to 3 at ten years, 1 to $2\frac{1}{2}$ in the adult female, and 1 to 2 in the adult male. The relative increase in the vertical extent of the face is considerable, and appears to go on gradually until adult life. In these respects it agrees with the descent of the larynx.

¹ *Die Charakteristik des Kopfes nach dem Entwicklungsgesetze desselben*, Berlin, 1845.

NOTE ON A RARE ABNORMALITY OF THE PANCREAS. By J. SYMINGTON, M.B., F.R.C.S.E., *Lecturer on Anatomy, Edinburgh.*

I RECENTLY obtained a fresh human pancreas and duodenum, removed in a *post-mortem* examination from an adult male subject. On distending the duodenum with air, in order to facilitate the dissection of the head of the pancreas, it was noticed that the upper part of the descending portion did not become dilated like the rest of the intestine, and on examination this was found to be due to its being completely surrounded in that situation by pancreatic tissue. Two processes of the pancreas passed from the upper part of the head of the gland towards the right side, one in front and the other behind the duodenum. They blended on its outer side so as to form with the head of the gland a ring of pancreas encircling the duodenum. The processes became somewhat narrower as they passed outwards, and the portion of gland on the right side of the duodenum was about half an inch in vertical extent. On dissecting out the ducts of the pancreas nothing unusual was observed in their arrangement. The common bile duct opened into the duodenum below the seat of constriction. The circumference of the distended duodenum, where it was surrounded by the pancreas, was two and a half inches, while above and below that it was more than three times as large.

Irregularities in the arrangement of the pancreatic ducts are comparatively common, but this does not appear to be the case with the glandular substance. There is no reference to an arrangement of the pancreas as above described in J. F. Meckel's *Handbuch der Pathologischen Anatomie*, or in Förster's *Missbildungen des Menschen*. The only case I can find recorded is one described and figured by A. Ecker in *Henle and Pfeufer's Zeitschrift*, xiii. Band, 1862.

I have presented the specimen to the Anatomical Museum of the University of Edinburgh.

ON THE EXISTENCE OF A FOURTH SPECIES OF THE
GENUS *BALÆNOPTERA*. By Dr G. A. GULDBERG,
Zootomical Museum, Christiania.

AMONG the representatives of the genus *Balænoptera* found in the North Atlantic, the following three species have long been well known, viz.:—*Balænoptera rostrata* (O. Fabr), *B. musculus* (Companyo), and *B. sibbaldii* (J. E. Gray).

The first named of these, the smallest of them all, being only 25 to 30 feet long, regularly visits the coasts of Greenland during the summer, and is found all the year round on the shores of Norway. Most European museums contain a skeleton of this animal, and they have often been stranded along the west coasts of Europe, from the North Cape to the Bay of Biscay. The second species, *B. musculus* (Companyo) (*Pterobalæna communis*, Van Beneden and Eschricht), is the species best known to the ancients. This animal is found over almost the whole of the Atlantic Ocean north of the Equator, in the Mediterranean, and in the Polar Ocean between Greenland, Spitzbergen, and Novoya Zembla. For the last ten years this animal has been regularly hunted on the coasts of Finmarken (Norway), to the west and the east of the North Cape. The animal visits these coasts regularly in pursuit of a small fish (*Osmerus articus*) "Lodde," which is found there in the spring in enormous quantities. The length of the adult animal varies between 60 and 70 feet.

The third species, *B. sibbaldii* (Gray), is the largest animal of the modern fauna, its length reaching 85 feet. This species is sometimes stranded on the northern coasts, and is plentiful on the Icelandic coast, and towards the south of Greenland. Since 1870 the animal also supplies the fisheries of East Finmarken. In 1878 eighty-eight specimens of this class were captured near Vadsö, a small town in the Bay of Varanger, and between 1881 to 1883 more than five hundred animals were taken in the same regions.

A fourth kind, *B. borealis* (Lesson), intermediate between *B. rostrata* and *B. musculus*, is admitted by some authorities, but certain naturalists have regarded it as a problematical species.

This doubt was justified owing to so few specimens having been captured.

Messrs P. van Beneden and P. Gervais, in their important work entitled *Ostéographie des Cétacés vivants et fossiles*, mention the following individuals :—

“The first specimen, which has been examined, is an animal 52 feet long. It came in 1811 from the coast of the Zuyder Zee, near Moniken Dam. The skeleton was acquired by the Royal Museum at Leyden.

“The second is a female, nearly the same size as the preceding, and was stranded on the coast of Holstein in 1819. The skeleton was acquired by the Berlin Museum. It is this skeleton which Rudolphi has described and drawn in his *Memoires de l'Academie de Berlin*, under the specific name of *rostrata*. Cuvier has reproduced its cranium under the name of ‘Rorqual of the North.’

“In July 1863 a third specimen of this kind was found on the coast of Norway, and its skeleton is preserved in the Museum at Bergen.

“The Royal Museum at Brussels also contains a skeleton sent from the North Cape to Professor Eschricht.”

According to P. Fischer (*Comptes rendus*, lxxxiii. p. 1298) an individual was stranded, July 29, 1874, near Biaritz (Basses Pyrénées), the skeleton of which is in the Museum at Bayonne. In September 1872 another one was taken in the Firth of Forth, the skeleton of which is in the Museum of the University of Edinburgh, and is described by Professor Turner in *Jour. of Anat. and Phys.*, April 1882, and also in the *Proceedings of the Royal Society of Edinburgh*, February 20, 1882. In 1883 a third specimen was taken at the mouth of the River Crouch, in Essex (Prof. Flower, *Proc. Zool. Soc.*, November 1883). The outward form and colour of *B. borealis* resemble the *B. musculus*, the skeleton having points peculiar to both *B. rostrata* and *B. musculus*. The number of vertebræ is fifty-five or fifty-six (*rostrata* forty-eight, *musculus* sixty-two), and the tail and shape of the cranium are also intermediate between those of the two above-mentioned species. Hence it seems many naturalists doubt the existence of this species.

Some naturalists believe, indeed, that it is only a large *B.*

rostrata (cf. *Rudolphi*), or perhaps a hybrid of the last mentioned and the *musculus*. I am not aware that anyone has, up to the present, observed hybrid individuals among cetaceans, but it is not impossible that some really exist. During last summer, two whaling captains communicated to me certain facts, from which I am inclined to believe in the existence of a hybrid between *B. musculus* and *B. sibbaldii*. According to the observations of these men, this hybrid is distinguished by many interesting peculiarities. Its length is about that of a *B. sibbaldii*, and the colour of the belly resembles that of *B. musculus*, but the colour of the back *B. sibbaldii*. The blubber is very thick, and the muscles are full of oil. The animal is very timid, and lives singly.

I add this short description of a supposed hybrid, in order not to omit calling attention to a very interesting probability.

After the excellent researches by Flower (*Proc. Zool. Soc.*, 1864, p. 397), by Van Beneden and Gervais (*l.c.*), by Turner (*l.c.*), and again by Flower (*l.c.*) last year, there cannot be any doubt in the mind of students that the *B. borealis* really exists, but it is quite certain that there is still much to be learned as to the characters of this species.

During my journey, in 1883, in Finmarken, I made some studies of the exterior of the *B. borealis*, and on the fins and skeleton of an adult specimen of this species.

Several specimens of this remarkable species have been captured during the last few years on the west coast of Finmarken. The whalers call this species "sejehval," because they appear on the coast at the same time as the "coal-fish" (*Gadus virens*, called in Norwegian "sej").

This cod does not serve as food for the whale, but it rivals it in pursuing and devouring the same innumerable small crustacea (*Thysanopoda inermis*) called "kril" by the Norwegian fishermen. This little animal is well known as forming the chief or only food of many fishes and whales (as, for instance, *B. sibbaldii*), and is often found in enormous shoals in these latitudes.

Thanks to the courtesy of Captain Bull, director of the fishing establishment at Sörvar (70½° N. lat.), and Mr A. Somerfeldt, a student, I have been enabled to make some very interesting researches as to the outward appearance and characteristics of this Balænoptera. Unfortunately no specimen was captured

during my stay at Sörvar, or I would have profited by the opportunity to obtain a sketch of an adult animal.

Length.—The average length of the *B. borealis* is about 40 feet, or 15 metres; it varies from 33 to 45 feet ($11\frac{1}{2}$ – $14\frac{1}{2}$ metres). The fishermen showed me one 46 feet, or 15·3 m. long, and two others of medium size which measured respectively 41 and 37 feet (13·6 m. and 12·1 m.). In any case, this whale does not exceed 50 feet or 16·6 m. in length.

Form and Colour.—At first sight the northern whale resembles the “finhval” (*B. musculus*), but its shape is more elegant. Its colour is black, and it does not show the bluish tint slightly seen in *B. musculus*, and readily observed in the blue whale (*B. sibbaldii*). This blue-grey shade is seen even in the darkest animals. Along the sides, and somewhat lower, the colour is mixed with whitish spots. The belly is entirely white with a reddish tint. The white part, corresponding with the stomach, does not extend much beyond the anus. How the region of the throat and lower jaw are defined from the colour, I have been unable to ascertain with accuracy. I have, however, been told that the semi-lateral white colour of the lower jaw, which is found in *B. musculus*,¹ where it is accompanied by a whitish tint of the fins, of the same side, does not exist in *B. borealis*. The lateral fins (anterior extremities) are very small and narrow as those of the “fin” whale; although externally dark they are lighter in colour than the back ones; internally they are greyish white. The dorsal fin is falciform, with a convex anterior edge and concave posterior edge. It much resembles that of *B. rostrata*, and is situated, as far as can be judged from the foetus, perpendicularly above the anus.

The baleen plates of this whale give the principal exterior signs which characterise and distinguish it. Their length is the same as those of the blue whale, but the upper extremity is much smaller. The longest plates measured by me had the following dimensions:—

	Metres.
Outside edge,	0·700
Inside edge,	0·880
The hairy edge a length of about	0·700
The upper edge or maxillary,	0·245

¹ The semi-lateral white colour, which Professor G. O. Sars has already described, is not confined exclusively to one side, but varies, according to my observations.

The outer edge in the longest fins is more or less concave; in the shortest, more rectilinear. The hairy part of the inside edge is more convex, because the plate, much lengthened, has the shape of a sword. The plates have not a flat surface, but, as is usually the case with the great divisions of Balænoptera, are slightly curved like an S, *i.e.*, the outside part of the plate is concave in front, and the inside presents a slight convexity directed forward. Five or six centimetres of the plates are encased in the epithelial substance, which is of considerable thickness at the buccal arch. The result is that the outside concave edge of the plate is only 65 centimetres long. In the large plates the upper edge (maxillary) makes an obtuse angle with the outside edge, but in the small ones this angle approaches nearer to a right angle.

The colour of the baleen plate is deep black; it resembles that of the blue whale; but the plate differs from other Balænopteriðæ in this, that it has *very fine hair of whitish or greyish colour*, resembling the hair of an old man or grey wool. These hairs, of remarkable fineness, constitute the most important character of these plates. In this respect the plates of the species in question more resemble those of the *Balæna mysticetus* than those of the *Balænopteriðæ*. The three other species of Balænoptera have, as a matter of fact, very thick hair on their baleen. The small plates are fawn-coloured or white inside, while the longer plates have a fawny, whitish streak, the length of their inside edge, on the upper part of which there is no hair. I have compared the above-mentioned plates with those of the skeleton in the Bergen Museum. Herr Nansen, custodian of the natural history section, was good enough to send me two plates of this specimen; they proved to be exactly similar to the small specimens of the adult individual obtained by me.¹

The skeleton at the Bergen Museum measured 27 feet (9 metres) in length, and the longest plate was 0.505 m.

I will now describe the fœtus and skeleton deposited by me in the Christiania Museum.

¹ These plates are covered with innumerable crustacea (Copepodes) in all stages of development, belonging evidently to the order *Balænophilus* of Aurevillius, and perhaps to the same species which, according to that writer, is a parasite on the plates of *B. sibbaldii*. Professor Van Beneden of Louvain will publish at some favourable opportunity a description of the species which lives on *B. borealis*.

In the early part of June 1883, Captain Bull, in accordance with my request, kindly sent to the Zootomical Museum of Christiania University a foetus sufficiently well preserved to enable me to give its exact outside measurements. This foetus, a female, was of the following dimensions :—

	Metres.
Total length,	1·355
Length of the head (from the anterior extremity of the upper jaw to the <i>meatus auditorius externus</i>),	0·345
Distance from the anterior extremity of the lower jaw to the umbilicus,	0·685
Distance from middle of umbilicus to the median groove in the caudal fin,	0·660
Length of right anterior limb,	0·185
Distance from anterior edge of the above to anterior extremity of lower jaw,	0·415
Size of anterior limb,	0·045
Dorsal fin, length at base,	0·068
Dorsal fin, height,	0·050
Distance from dorsal fin to caudal groove,	0·417
Distance from dorsal fin to extremity of lower jaw,	0·875
Breadth of caudal fin,	0·332
Distance from the <i>anus</i> to the caudal aperture,	0·405
Distance from the <i>anus</i> to the centre of the umbilicus,	0·250
Distance from the <i>anus</i> to the extremity of the lower jaw,	0·950

The dorsal fin is falciform; a vertical line from its posterior extremity passes through the *anus*.

The head is equal to a quarter and three-tenths of its whole length; the anterior limbs equal a seventh and three-tenths of its length, and the dorsal fin is one twenty-seventh of the length of the body. The latter is situated between the posterior and the middle of the body.

The upper jaw is a little curved inwards, making a slight concavity, as it is very narrow and pointed.

The ventral grooves are 64 in number.

The bones of the skeleton at Christiania are as follows :—

Cranium, omoplate, the tympanic bone, pelvic bones, the third cervical vertebra.

The length of the skull is 3·08 m.; the maxillary region is 6 feet 10 inches (2·16 m.), and its breadth in front of the orbits 0·91 m.

In 1882 I brought back the three first cervical vertebræ of an animal captured near the North Cape (in the Tufjord). These vertebræ probably belonged to an old whale, as the body of the bones was solid along the lower edges, leaving a space along the lateral and upper sides. The last traces of epiphysis have disappeared. The spinal apophyses are very high, and the axis carries the largest; this is directed slightly forward. The atlas and third cervical vertebra carry spinal apophyses, more vertical; that of the last is fine and sharply pointed.

The atlas carries very deep articular cavities for the occipital condyles. The large diapophyses are large and short; they project outside, while the size of the base exceeds the length.

On the lower surface of the atlas traces are seen of a small apophysis, directed backwards, blended with the body of the axis. On the upper side of the diapophysis a small thick and triangular metapophysis is observed, directed a little in front. The vertebral arches are very strong, and support a large spina lapophysis, vertically. The dimensions of the atlas are:—

	Metres.
Greatest height,	0·330
Greatest breadth,	0·480

The axis has the transverse apophyses very well developed, the parapophyses (*i.e.*, the lower transverse apophyses) are almost double the size of the diapophyses. The transverse orifice is, proportionately, very small, while the vertical plate of the transverse apophysis, formed by the juncture of the dia- and parapophyses is very large, and about two and a half times the transverse diameter of the transverse orifice (0·24 m. to 0·10 m.). On the upper edge of the diapophysis, there is, as on the atlas and third cervical vertebra, a small metapophysis, the extremity of which is directed forward. I have already mentioned that its conical, spinal apophysis much exceeds the others in height.

The following are the dimensions of the axis:—

	Metres.
Greatest height,	0·380
Greatest breadth,	0·785
Thickness of the body,	0·100

The third cervical vertebra, where, as usual, the junction of the extremities of the dia- and parapophyses occurs, has a very large transverse orifice. The dimensions of the third cervical vertebra are as follows:—

	Metres.
Greatest height,	0·350
Greatest breadth,	0·660
Height of the vertebral body,	0·165
Breadth of the vertebral body,	0·220
Size of the vertebral body,	0·050

The following are the dimensions of the third cervical vertebra belonging to the previously mentioned cranium:—

	Metres.
Greatest height,	0·280
Greatest breadth,	0·680
Height of body,	0·160
Breadth of body,	0·203
Size of body,	0·050

The breadth of the omoplate is about double its height. It is distinguished by its extremely elegant shape; the surface is very smooth and its thickness is only 0·005 m. at the narrowest part. The upper edge is very convex, the back edge is slightly concave at its lower part, and the anterior edge is rectilinear. The *acromion* is very large, and becomes broad in front; it is slightly bent upwards and forms an acute angle with the anterior edge of the omoplate. The coracoidal apophysis, on the other hand, becomes narrow in front; it rapidly widens inwards, and a little upwards. The glenoidal cavity is oval.

The dimensions of the scapula are as follows:—

	Metres.
Greatest width or length,	1·035
Greatest height,	0·615
Approximate length of the acromion,	0·250
Middle diameter of coracoidal apophysis,	0·150

The pelvic bones are not alike on each side. The right one

is 0.250 m. long, the left, bent like an S, is rather distorted, its length being 0.220 m.

The tympanal bone chiefly resembles that of *Balænoptera musculus*, the principal distinction being its flat form and pointed extremities. Its greatest length is 119 mm., diameter 56 mm., and height 86 mm. Professor Turner (*l.c.*) compares the tympanal bones of *B. rostrata*, *B. sibbaldii*, and *B. borealis*, and remarks that a peculiarity of the latter is the relative want of breadth.

If this description is compared with that of Professor Lilljeborg in *Oversigt af de inom Skandinavien antræffede hvalartede daggdjur Upsala Universitets årsskrift*, 1878, page 25; idem, *Sveriges och Norges Ryggradsdjur*, 1 Daggdjuren 2^{den} Del., page 945; of J. E. Gray, *Catalogue of Seals and Whales in British Museum*, 1868 and 1870; idem, *Proc. Zool. Soc.*, 1864, p. 223; Professor Flower, *Proc. Zool. Soc.*, 1864, p. 399; of Van Beneden and Gervais, *Osteographie des Cétacés vivants et fossiles*, p. 252, and pls. x. and xi., figs. 11-35; Professor Turner, *Journal of Anatomy and Physiology*, April 1882, pp. 471-484; Professor Flower, *Proc. Zool. Soc.*, 1883, pp. 113-117; from these I have come to the conclusion that all the essential characteristics are identical. I admit there are some slight differences, but these do principally arise from difference in age. Most of the specimens described are far from being adults, though Professor Turner has described in *Jour. of Anat. and Phys.*, 1882, a specimen 38 feet long, which must therefore be an adult. Of previous writers Professor Turner alone has given a detailed description of the baleen, Professor Lilljeborg only referring to it casually. But I believe nobody has hitherto called attention to the fineness and thinness of hair on the plates, by which this species is distinguished from other Balænopteridæ.

All the specimens observed up to the present, leaving out of consideration *B. Schlegelii*, Flower, and *Sibbaldius tuberosus*, Lilljeborg, have been found on the coasts of Northern Europe, from the south-west coast of France to the North Cape. Nevertheless, whalers have seen and captured the "sejehval" as far as Vardó and Vadsó, on the east coast of Finmarken, viz., in the same longitude as St Petersburg. It is, however, quite exceptional that this variety is found east of the North Cape.

According to the experience of Captain Bull, who has hunted this whale for the last five years, the *B. borealis* only approaches the coast in the summer. At the end of May it appears at from 5 to 10 leagues from land. In June and July it enters the fjords. It has been captured as late as September, but generally disappears earlier. In its migratory summer visits to the Norwegian coast, it much resembles the blue whale (*B. sibbaldii*), as this species only approaches the coast during the summer. Last year very few "seje" whales appeared on the Norwegian coast, and I am informed that Captain Bull only caught four or five specimens, whereas he caught forty-eight in 1883.

As I have already mentioned the "sejehval" and also the *B. sibbaldii* feeds on small crustacæ, *Thyssanopoda inermis*. It is not known, for certain, whether these animals also eat fish.

In Professor Lilljeborg's important work *Sveriges och Norges däggdjur*, this species is called "silhval," viz., "herring whale"; and the author supposes that these whales pursue these enormous shoals of herrings.¹ That may be possible, but perhaps it is less to prey on the herrings than upon the small animals upon which the latter also live. It seems to me that the hairs of the fins, very fine and slender, and greatly resembling those of the Greenland whale, are made purposely to retain small invertebrate animals.

Among the Balænopteridæ the *B. borealis* has the best flesh, and during recent years the flesh has been skinned for eating. The colour of the flesh is about the same as beef, while that of other Balænopteridæ is much darker. The oil of this species of whale is very fine, containing less stearine than that obtained from other species.

¹ We know for a fact that the *B. musculus* and *rostrata* follow the herring shoals.

**SOME VARIATIONS IN THE ANATOMY OF THE
HUMAN LIVER.** BY ARTHUR THOMSON, M.B., *Demon-
strator of Anatomy, University of Edinburgh.*

CASE 1. An unusual arrangement of the lobes of the liver was lately observed in the dissection of an aged female subject in the anatomical rooms of the University of Edinburgh. The most striking feature in the specimen was the presence of an accessory lobe of considerable size, which was connected with the free margin of the right lobe close to the anterior extremity of the longitudinal fissure.

Description of the Liver on Removal.—The liver was small—greatest transverse diameter, 10 inches; greatest antero-posterior diameter of right lobe, 5 inches; greatest antero-posterior diameter of left lobe, $4\frac{1}{2}$ inches; weight $22\frac{1}{2}$ oz. Projecting from the anterior margin of the right lobe there was a tongue-like process of liver substance which measured $2\frac{1}{2}$ inches in length from its base to its most dependent point; the left margin of this process was in close relation to the anterior extremity of the longitudinal fissure. From this point, towards the right, its attachment to the anterior border of the right lobe measured 3 inches.

On examination of the under surface of the gland the following facts were noted:—

The under surface of the left lobe was normal.

The arrangement of the fissures and lobes to the right of the longitudinal fissure was as follows:—At a point corresponding to the junction of the anterior and middle thirds of the longitudinal fissure, the “transverse” fissure passed obliquely forwards and to the right, towards the point at which the right margin of the tongue-like projection of liver substance joined the anterior margin of the right lobe. The hepatic ducts, the hepatic artery, and the portal vein were found in this fissure in the order stated from before backward. Each of these structures was connected near the anterior extremity of this oblique fissure with the branches which entered a small fissure on the under surface of the accessory lobe, close to the point at which this lobe was connected with the margin of the right lobe.

Anterior to this obliquely placed hilus the liver substance was disposed as follows:—Passing forward from the hilus, about 1 inch from, and parallel to, the longitudinal fissure, was a deep sulcus, which, as it approached the free margin of the liver, became much broader and shallower; at this point its roof was formed by a double layer of peritoneum as that serous membrane was reflected from the upper on to the under surface of the organ. In this fissure the gall bladder was lodged. Between this fissure for the gall bladder, and the longitudinal fissure, there was a small nodule of liver substance about the size of a small walnut; this represented the quadrate lobe, anteriorly; this was prolonged forward for about 1 inch as a little tail-like process which lay between the layers of the peritoneal fold already described.

The under surface of the accessory lobe presented a pyriform appearance, separated from the right lobe by the oblique hilus, and from the little lobe above described by the fissure for the gall bladder.

Posterior to the hilus, the under surface of the organ presented much the usual appearance. The Spigelian lobe was well marked, and was connected in front with a very distinct caudate lobe; the anterior extremity of the caudate lobe, instead of being rounded off into the gland substance, about the middle of the under surface of the right lobe, reached to within $\frac{3}{4}$ of an inch of the anterior free margin of the organ, and close to the point at which the right margin of the accessory lobe was fused with the anterior border of the right lobe; the caudate lobe was separated from the accessory lobe by the various structures entering the hilus.

Unfortunately, I had no opportunity of examining the liver *in situ* in the abdominal cavity, as my attention was not directed to the subject until after the viscus was removed; but from what I can gather from the statements of the dissectors of the part, its position was somewhat as follows:—

The lowest part of the accessory lobe, already described, projected a little less than $\frac{1}{2}$ an inch below the ninth right costal cartilage. To the right, and external to this, the anterior border of the right lobe receded under cover of the costal margin as much as 2 inches, the hepatic flexure of the colon ascending to a correspondingly higher level.

From these facts, and also from the examination of the organ, I am inclined to think that the abnormality consists rather in the suppression of the development of a part of the right lobe, than in the addition of a supplemental portion of gland substance.

There was no evidence of disease in the organ, nor was there any indication of tight lacing having been practised during life.

The case is of some interest from the point of view of the physician, as grave error in diagnosis might have resulted from the physical examination of this subject during life.

It would have been a most natural conclusion to have arrived at, that the patient was suffering from extensive atrophy of the gland; and it is not at all improbable that the abnormal lobe, here described, might have been mistaken for a distended gall bladder. Frerichs¹ has pointed out that congenital malformations of the liver may lead to such mistakes; but, so far as I am aware, no case has been recorded where such a condition might give rise to the physical diagnosis of atrophic changes, as hinted at above.

Case 2. The next case is a somewhat rare and interesting condition, in which *the hepatic veins opened directly into the right auricle of the heart.*

On laying open the cavity of the right auricle three orifices were observed opening into its lower and posterior part. By thrusting the fingers into these openings two were seen to pass directly into the liver substance immediately below the diaphragm, whilst the third, or intermediate in position, of these venous channels was recognised as the inferior vena cava. The aperture of this vessel was much smaller than usual, otherwise it was normal in position and direction.

As regards the position and size of the hepatic veins, they were as follows:—The larger of the two was about half the calibre of the inferior cava, and lay to the left side of the orifice of that vessel, separated from it by a double fold of endocardium and subjacent tissue of about $\frac{1}{2}$ of an inch in thickness. On looking into the opening of this hepatic vein, a vessel of considerable size was seen to join it just prior to its entrance into the auricle. By thrusting a probe down these vessels they were found to arise within the substance of the left lobe of the liver.

¹ *Diseases of the Liver*, New Sydenham Society, 1860, vol. i. p. 41.

In front of, and to the right of, the caval orifice lay the mouth of the other hepatic vein, somewhat less in size than the above; similarly, it was separated from the opening of the inferior cava by a double layer of endocardium and subjacent tissue. On examining the surface of the inter-auricular septum two shallow grooves could be traced upward towards the fossa ovalis from the mouth of the inferior cava, and the hepatic vein which lay to its left side—the double fold of endocardium separating these two openings being prolonged upwards and forming the ridge which separated the two grooves. There was little or no trace of an Eustachian valve. What was apparently the remains of that structure lay to the left of the mouth of the left hepatic vein (between this vein and the right auriculo-ventricular opening), and passed upwards to blend with the thickened margin of the annulus ovalis. There was no evidence of enlargement of the heart. The valves, with the exception of the aortic, in which there was slight atheromatous deposit, were healthy.

Similar cases are recorded in vol. iii. of Henle's *Anatomy*,¹ wherein are quoted Morgagni and Huber.

In the instance described by Rothe² the hepatic vein entered the base of the right ventricle, its mouth being guarded by three valves. Hyrtl,³ in his notes of the examination of the body of a deaf and dumb boy, seven years old, mentions that—"All the hepatic veins joined in a thick common trunk, which did not as usual enter the ascending vena cava, but passed through the diaphragm on the left side of that vessel, and emptied itself into the venous auricle of the heart." He also quotes Frid Gurlt as having recorded a similar condition.⁴

¹ Henle, *Anatomie des Menschen*, vol. iii. pp. 388, 389.

² *Transactions of Joseph's Academy*, 1787, vol. i. p. 267.

³ *Österreiches medicalisches Jahrbuch*, 1836, xi. 425.

⁴ *De Venarum deformationibus*, Vratistlaw, 1819, p. 22.

**SOME OBSERVATIONS IN REFERENCE TO BILATERAL
ASYMMETRY OF FORM AND FUNCTION.** By
FREDERICK TUCKERMAN, M.D., *Lecturer on Anatomy and
Physiology, Massachusetts Agricultural College, U.S.A.*

THE following data in animal physics are chiefly interesting from their bearing on the question of right and left-sidedness in relation both to form and function.

During the past autumn anthropometric observations were made upon over fifty students of the Massachusetts Agricultural College, and, as a result, nearly three thousand measurements have been recorded.

The average age was nineteen years and six months: minimum and maximum age sixteen years and twenty-six years respectively. The average weight was 67·8 kilos. The average height, 1·730 m., and the average horizontal length, 1·742 m.

It is quite generally known that the horizontal length of the body almost always exceeds the height. This was found to be so in 90 per cent. of the cases, the average difference being 12 mm.

The greater number showed the right leg longer than the left. The difference in length between the right and left leg was found to be sometimes in the femur and sometimes below the knee. The longer leg generally had the greater girth. When the left leg was the longest the right arm was found to be the longest, as is the case when the right leg is longest. Eighty per cent. showed the right knee to be farther from the ground than the left.

The right arm was the longest in 80 per cent. of the cases; the average difference between the length of the right and left arm being 14 mm. The difference in the length of the arm was sometimes in the humerus, sometimes in the bones of the fore-arm, and sometimes below the wrist.

The girth of the right arm was greater than the left in nearly 90 per cent. of the cases. The girth of the fore-arm is usually a measure of the strength of the hand. The right fore-arm was almost invariably the strongest. The difference

between the right and left girths of the lower extremities was, as would be expected, greater on the right side than on the left; but the difference was not nearly so marked as in the upper extremities.

Chest Girth (full and in repose).—54·32 per cent. showed the right chest the longer, 17·38 per cent. the left chest, and 28·30 per cent. showed no difference between the two sides. In twenty-one cases where the right chest was the largest, nineteen showed the right arm the longest. In eight cases where the left chest was the largest, five showed the left arm the longest; and in thirteen cases where there was no difference between the two sides of the chest, eight showed the right arm the longest.

The abdominal girth showed a considerable difference in favour of the right side.

A given weight felt heavier in the left hand than in the right in a large proportion of the cases.

The right eye was the eye most used in nearly every instance. In the only pronounced case of left-handedness the left eye was preferred.

A CASE OF EXOSTOSIS OF THE ULNA. By R. J. ANDERSON, M.A., M.D., *Professor of Natural History, Queen's College, Galway.*

THE following example of a very rare form of exostosis of the ulna was found in the Belfast Anatomical Rooms during the Session 1880-81. The subject was a female aged 50 years. The conformation of the fore-arm was for the most part normal. A tumour was felt at the junction of the middle and lower thirds of the fore-arm—the position of the interosseous space.

The removal of the soft parts showed that the tumour was attached to the ulna, and the bony projection was received into a concavity in the radius. The measurements of the radius, ulna, and the interosseous space, are here given in millimeters:—

Measurements of Radius—

From styloid process to head, . . .	23·9
Transverse diameter of head, . . .	2·4
Transverse diameter at tuberosity, . . .	1·8
Transverse diameter at the upper end of cavity, . . .	1·9
Transverse diameter at middle of cavity, . . .	1·8
Transverse diameter at lower end of cavity, . . .	2·3
Transverse diameter of lower end, . . .	3·3

Measurements of Ulna—

From styloid process to olecranon, . . .	25·5
From styloid process to coronoid, . . .	23·0
Transverse diameter of olecranon, . . .	3·0
Transverse diameter at narrowest part, . . .	2·4
Transverse diameter of coronoid, . . .	2·8
Shaft at upper border of exostosis, . . .	1·6
Shaft at lower border of exostosis, . . .	2·0
Transverse diameter at lower border, . . .	2·0

Measurements of Exostosis—

Distance of the articular surface from the posterior border of the ulna behind, . . .	3·0
Do. do. in front, . . .	2·0
Neck (longitudinal diameter), . . .	1·5
(antero-posterior diameter), . . .	1·0

Head (longitudinal diameter),	.	.	2.0
(antero-posterior diameter),	.	.	1.6
Socket (longitudinal diameter),	.	.	2.4
(antero-posterior diameter),	.	.	1.9
Upper part of interosseous space,	.	.	.13
Lower longitudinal diameter,	.	.	4.2
Greatest breadth,	.	.	1.2

The shaft of the radius is normal for the upper two-thirds of its extent. The shaft becomes wider at a distance of 7-8 cm. from the lower extremity, and here the inner part is marked by a large cavity, the measurements of which are given above. It is lined with cartilage, and its border projects at the lower part. The long axis is nearly parallel to the long axes of the bones. The anterior surface of the radius at and below the cavity is somewhat flattened. The posterior surface is not much changed except where it is encroached upon by the articular facet. A slight ridge runs downwards and outwards from the lower end of the cavity.

The ulna, at a distance of 7.3 cm. from its lower extremity, increases in size, and diminishes again further down. The enlargement is marked by a furrow near the middle, and half an inch further down by a ridge,—this ridge runs downwards and inwards from the lower part of the exostosis, and ceases near the anterior part of the inner surface of the ulna. The posterior surface is greatly increased in breadth, and is marked by a vertical groove close to the exostosis. The exostosis consists of a neck and head; the former is flattened from before backwards, the latter presents a well-marked articular surface, sharply limited and covered with cartilage. A capsule and synovial membrane are present, the former being attached round the articular cavity. The interosseous membrane is attached to both bones—the exostosis and the capsule.

THE *MUSCULUS STERNALIS* AND ITS OCCURRENCE
IN (HUMAN) ANENCEPHALOUS MONSTERS. By
FRANCIS J. SHEPHERD, M.D., C.M., *Professor of Anatomy*
in McGill University, Montreal. (PLATE XV.)

At the meeting of the British Association held last summer in Montreal, Professor D. J. Cunningham, of Dublin, read a paper on "The Value of Nerve-Supply in the Determination of Muscular Anomalies," in which he stated his belief that the *musculus sternalis* belonged to the pectoral group—in fact, was an aberrant portion of the *pectoralis major*, as recently suggested by Mr Abraham, of Dublin.¹ Professor Cunningham had traced the nerve-supply² of the *musculus sternalis* in five cases, and found that it came from the internal anterior thoracic nerve, a proof he thought that it belonged to the pectoral group. He also threw out the suggestion that this might possibly be a new inspiratory muscle antagonistic to the *triangularis sterni* appearing in man (for it acted when well developed as an elevator of the ribs), and stated his impression to be that it occurred more frequently in females, as costal inspiration is more pronounced in women than in men.

In the discussion which followed, both Dr G. E. Dobson and myself held that the *musculus sternalis* was most likely a remnant of the *panniculus carnosus*. Dr Dobson considered that the *sterno-cuticularis* muscle of the hedgehog closely corresponded to the *musculus sternalis*.

Professor Cunningham also mentioned in his paper that Mr Abraham had recently found the *musculus sternalis* to occur very commonly in anencephalous monsters, as he had seen it in six out of eleven specimens examined.

Since the meeting of the British Association I have examined six anencephalous monsters which are in the museum of the Medical School of McGill University, and have found in each one a well-marked example of the *musculus sternalis*. My recent dissections of these monsters has had the effect of changing

¹ *Trans. Acad. Medicine in Ireland*, vol. i., 1883.

² *Jour. Anat. and Phys.*, January 1884.

my previous views in regard to the homology of this muscle. I have been convinced that it does not belong to the panniculus group, but very probably should be classed with the pectoral group for the following reasons:—

1. In seven out of the nine muscles found in these monsters (three had double muscles) the nerve-supply was furnished by the anterior thoracic; one of these seven, however, in addition, received a small branch from one of the intercostal. In the other two muscles, occurring in the same foetus, I was unable to satisfactorily make out the nerve-supply, but am inclined to believe it came from the anterior thoracic (Case III.).

2. In three the fibres of the abnormal muscles were continuous with those of the greater pectoral (figs. 1, 2, 6), and in one (fig. 5) the fibres pierced the greater pectoral.

3. In several the insertion of the musculus sternalis was covered by the pectoralis major, and the origin was in common with the upper sternal fibres of the pectoralis major (figs. 1, 4, 6).

4. The greater pectoral was deficient on the side on which the musculus sternalis was present in eight cases (figs. 1, 2, 3, 5, 6).

5. In one (Case VI.) the right *platysma myoides* was well developed, and passed some distance below the clavicle. It was separated from the musculus sternalis of that side by fascia and a thick layer of fat, and was on a plane quite superficial to the musculus sternalis.

In all the cases except one (fig. 3) the abnormal muscle was quite large and well developed, and had an attachment to the sternum and costal cartilages. The majority of the muscles were triangular in shape, though some were fusiform. In the last three dissected I had no difficulty in tracing the nerve-supply, as the nerve was always found passing along the interval which existed between the two portions of the greater pectoral, thence over the pectoralis minor, through the costo-coracoid membrane, to the internal anterior thoracic nerve. The nerve always entered the muscle on its deep surface. In three of the subjects the muscles were continuous with the sternal insertion of the sterno-mastoid (figs. 1, 2, 4). In two a portion of the muscle blended with the aponeurosis of the external abdominal oblique.

I do not propose in this paper to discuss all the various views that have been held in regard to the homology of the musculus sternalis, as this has already been ably done by Professor Turner¹ and others; but I might mention that Professor Bardeleben² has advanced the theory that some of these muscles belong to the sterno-mastoid, and are supplied by the intercostal nerves, whilst others should be classed with the pectoral group, because they receive their nerve-supply from the anterior thoracic. Malbrancé's³ observations agree with Bardeleben's, for in two living subjects he found the musculus sternalis standing out quite perceptibly under the skin.

In the first case faradisation of the intercostal nerves brought the muscle into action, but in the second it failed; but when faradisation of the thoracic nerves was employed, the muscle responded immediately.³

M. Testut⁴ holds that the musculus sternalis (præ-sternal) is in its upper part an appanage of the sterno-mastoid, and in its lower belongs to the external abdominal oblique. He says these muscles (sterno-mastoid and external abdominal oblique) are in the same muscular plane, and that the musculus sternalis is the remnant in man of the old connection which formerly existed between the two—a connection which exists in serpents.

As I said above, I feel disposed to consider the musculus sternalis as belonging to the pectoral group, and await further light to determine its proper morphological significance. In some of my cases it appeared to take the place of the absent portion of the greater pectoral, and where the muscle was well developed would act as an elevator of the ribs.

As to its occurrence in anencephalous monsters, I am unable to afford any explanation. As far as I can judge from the six specimens I have examined, it appears to be the normal condition. There seems to be great variety of origin, insertion, size, and shape of these muscles, no two being exactly alike. The fact that this muscle occurs so commonly in the brainless monsters would point rather to its being a rudiment than a new

¹ *Jour. of Anat. and Phys.*, vol. i. p. 246.

² Quoted by Testut in *Les Anomalies Musculaires chez l'homme*, 1884.

³ In Case III. in my series the muscle was supplied by both intercostal and anterior thoracic nerves.

⁴ *Les Anomalies Musculaires chez l'homme*, p. 84.

muscle appearing in man. For it is in these cases of arrest of development we should expect to find reversions, rudiments, and anomalies. On the other hand, no arrangement of any existing pectoral group resembles that found in these brainless monsters.

The proportion of female anencephalous monsters is very large in my series—five out of six are females; and as far as I can learn it is rather the exception for an anencephalous monster to be of the male sex.

The cases described in detail are as follows:—

CASE I. (fig. 1). *Female fœtus, full term. Anencephalous. Musculus sternalis unilateral. Left.*

The musculus sternalis in this specimen is of large size, and arises from the fascia over the first piece of the sternum by a flat tendon, which is continuous above with the sternal origins of both sterno-mastoid muscles, and on the right side is connected with the muscular fibres of the greater pectoral arising from the manubrium. From this origin the muscle passes downwards and outwards to the left side, expanding as it descends into a large fusiform muscle, which is inserted into the whole of the fourth left costal cartilage and into the side of the sternum opposite the fifth and sixth cartilages; the innermost portion of the muscle is prolonged downwards over the lower part of the greater pectoral, and ends in the aponeurosis of the external oblique muscle of the abdomen.

The abnormal muscle lies on the sternum and costal cartilages, and has only a few of the deeper fibres of the greater pectoral beneath it. Above, on the outer edge, some muscular fibres came off from the musculus sternalis, and passing outwards form part of the greater pectoral muscle.

The nerve supplying the muscle enters its under surface about half-way down the muscle; it can be traced outwards through a cellular interval in the greater pectoral, over the pectoralis minor, to its upper border, where it pierces the costo-coracoid membrane, and joins the internal anterior thoracic nerve. As it lies between the two pectorals it gives off a branch to the lower part of the great pectoral.

CASE II. (fig. 2). *Female fœtus. Anencephalous, with spina bifida of cervical and upper dorsal regions. Musculus sternalis bilateral.*

The two muscles have a common origin from the first piece of the sternum, which is continuous above with the sternal portions of both sterno-mastoid muscles. The *left* muscle, smaller than the right, consists of a flat narrow band of muscular fibres, which pass down from the common origin to be inserted into the third left costal cartilage and side of the sternum. At its insertion it is covered by the fibres of the lower segment of the greater pectoral. The *right* muscle is large and flat, and, besides the origin common to it and its fellow, is attached to the sternum opposite the second and third costal cartilages. It divides into three sets of muscular fibres—the outer inserted into the upper border of the lower segment of the pectoralis major, the middle continuous with the fibres of that muscle, and the inner inserted into the lower end of the sternum and upper part of the ensiform cartilage. On both sides a triangular portion of the greater pectoral is absent; the spaces thus left are partly covered by the abnormal muscles. This space is longer on the left than the right side. In this fœtus, owing to its very friable condition, I was unable satisfactorily to trace the nerve-supply of these anomalous muscles, but am inclined to believe that the nerve-supply comes from the anterior thoracic, as on each side I traced a branch from the anterior thoracic over the lesser pectoral to the triangular interval between the two segments of the great pectoral, but there I lost it.

CASE III. (fig. 3).—*Female fœtus. Anencephalous with spina bifida of cervical region. Musculus sternalis unilateral. Left side.*

In this case the abnormal muscle consists of a small fusiform slip which arises from the sternum opposite the second costal cartilage by a thin aponeurosis, passes down over the left greater pectoral a little outside the sternum, and finally expands into a broad aponeurosis, which blends with the fascia over the external abdominal oblique. It receives its nerve supply from two sources. The larger nerve, which enters the middle of the muscle, can be traced through the greater pectoral over the lesser pectoral, and through the costo-coracoid membrane to the

internal anterior thoracic. The smaller enters the muscle nearer its upper end, and can be traced through the intercostal space to the third intercostal nerve. Both nerves supply the muscle from its deep surface. This is the only case where a branch from the intercostal could be traced to the muscle itself. In several of the other cases the intercostal nerves pierced the muscle, but gave no branches to it. No portion of the greater pectoral is absent in this case.

CASE IV. (fig. 4).—*Male fœtus. Anencephalous with spina bifida of cervical region. Musculus sternalis unilateral. Left.*

The abnormal muscle in this fœtus is of large size, flat and triangular, arises by a tendon from the manubrium, in common with the upper sternal portion of the right pectoralis major and the sternal portion of the left sterno-mastoid with which its left border is continuous. As it passes down to the left it soon expands into a broad muscle which is inserted into the third costal cartilage. At its insertion it is covered by the fibres of the pectoralis major. Its inner edge is prolonged downwards over the lower portion of the last mentioned muscle. On the left side a triangular portion of the pectoralis major muscle, arising from the upper part of the sternum and costal cartilages of the second and third ribs, is wanting, the space left being partly covered by the musculus sternalis.

The nerve supplying the muscle can be seen crossing the triangular interval, and can be traced, as in the other cases, to the anterior thoracic.

CASE V. (fig. 5).—*Female fœtus. Anencephalous in spina bifida. Musculus sternalis bilateral.*

Both muscles arise in common with the upper sternal fibres of the pectoralis major from the manubrium, and diverge from each other as they descend.

The *left* muscle passes down over the sternum and left costal cartilage, and is inserted into the fourth costal cartilage near the sternum. It is a flat triangular muscle of considerable size. Continuous with its lower fibres, and running along its inner edge, is a small muscular slip which has an attachment above by a round tendon to the middle of the sternum, passes over the

lower part of the greater pectoral, and is inserted into the fascia covering that muscle. A large portion of the central part of the pectoralis major is absent, the space left, as in the other cases, being partly covered by the abnormal muscle. The nerve supplying the muscle crosses this vacant interval, and can be traced, as in the other cases, to the internal anterior thoracic.

The *right* muscle goes down and out from the common origin, and soon divides into two slips, the outer of which, after piercing some fibres of the greater pectoral, is lost in the fascia covering that muscle. The inner slip continues down immediately to the right of the sternum, and ends in a tendinous expansion which is inserted into the fascia of the lower part of the pectoral muscle. On this side also the portion of the great pectoral is deficient which arises from the second and third costal cartilages and the corresponding portion of the sternum. The nerve can be traced crossing the triangular interval, and under the upper segment of the greater pectoral to join the anterior thoracic above the lesser pectoral.

CASE VI. (fig. 6).—*Female fœtus. Anencephalous with spina bifida of cervical and upper dorsal regions. Musculus sternalis bilateral.*

The muscles of the two sides have a common origin from the manubrium.

The *right* muscle, triangular in shape, is the larger. It soon becomes muscular, crosses the triangular interval caused by absence of a portion of the great pectoral, and is inserted by muscular fibres into the upper border of the lower segment of the greater pectoral, and also into the sternum opposite the fourth costal cartilage. Some of its fibres pass over the pectoral muscle and blend with it. As in the other cases, it is supplied by a branch from the internal anterior thoracic nerve, which reaches the muscle in the usual way.

The *left* muscle divides into two portions, the outer of which is the larger, flat and ribbon-shaped, passes down over the triangular interval between the upper and lower segment of the greater pectoral, and is inserted into the third costal cartilage; the inner portion has an additional origin from the second piece of the sternum. It continues down, over, and to the left side of

the sternum, developing into a fusiform-shaped muscle, which ends by dividing into two tendinous slips, one of which is inserted into the lower end of the sternum, and the other into the fascia covering the pectoralis major. The nerve-supply is, as in the other cases, furnished by a branch from the internal anterior thoracic nerve, which joins the deep surface of the muscle after pursuing the usual course across the lesser pectoral and vacant interval between the two parts of the greater pectoral. In its course a small branch is given off, which goes to the lower part of the greater pectoral.

On each side there is a deficiency of the great pectoral, a triangular portion arising from the second and third costal cartilages being absent. The interval is larger on the right than the left side, and on each side is partially covered by the abnormal muscle.

In this foetus on the right side the platysma myoides is strongly developed, continues over the clavicle, and reaches for some distance below it. It is a well-developed muscle, and is separated from the musculus sternalis of that side by fascia and a thick layer of adipose tissue, so that it is on a plane quite superficial to the musculus sternalis.

Note.—I have, in adults, only seen the musculus sternalis three times¹ in three hundred subjects. Some cases, no doubt, escaped my notice, owing to the majority of the subjects having been injected through the heart, and, in consequence, the sternum having been sawn through the centre. In all the cases seen the muscle was well developed. In one case it was continuous above with the opposite sterno-mastoid, and below was attached to the cartilage of the fifth rib. In the second case it arose from the second costal cartilage, and passed down over the pectoral muscle, and ended by being inserted into the fascia covering that muscle. Some of its upper fibres intermingled with those of the platysma myoides. The subject was very thin.

In the third case the muscle was attached above and below to the fascia covering the greater pectoral. All three muscles occurred in males. Two of the muscles were on the left side and one on the right.

¹ *Annals of Anatomy and Surgery*, 1881-83.

EXPLANATION OF PLATE XV.

Fig. 1. Left musculus sternalis, arising from the first piece of sternum, and continuous with the sterno-mastoids, inserted into the fourth costal cartilage and side of sternum—a portion continuous with the left pectoral. Nerve-supply from anterior thoracic. (Female.)

Fig. 2. Double sternalis muscle, arising from manubrium, and, in common with upper fibres of great pectoral and sterno-mastoid, inserted on right side into sternum and great pectoral, on left into third costal cartilage. Sternal and costal origins of both greater pectorals defective. (Female.)

Fig. 3. A slender left musculus sternalis, arising from sternum opposite second costal cartilage, and inserted into the aponeurosis of external abdominal oblique. Supplied by a branch from anterior thoracic nerve and intercostal. (Female.)

Fig. 4. Left musculus sternalis, arising from manubrium, in common with sterno-mastoid and upper fibres of greater pectoral inserted into third costal cartilage. Nerve-supply from anterior thoracic. Left pectoralis major deficient in central part. (Male.)

Fig. 5. Double musculus sternalis, arising from manubrium, with upper fibres of greater pectoral on right side. Two slips piercing pectoral muscle, and inserted into aponeurosis covering that muscle. Muscle on left side inserted into fourth costal cartilage. Nerve-supply from anterior thoracic on both sides. (Female.)

Fig. 6. Double musculus sternalis, arising from manubrium. Right side flat muscle inserted into greater pectoral and sternum. Left side, two slips—one inserted into third costal cartilage, and other into aponeurosis of greater pectoral. Nerve-supply from anterior thoracic on both sides. Both greater pectorals defective. (Female.)

THE VENOUS SYSTEM OF THE BLADDER AND ITS
SURROUNDINGS. By E. HURRY FENWICK, F.R.C.S.
Eng., *Assistant Surgeon to the London Hospital, Surgeon to
St Peter's Hospital for Stone, &c.* (PLATE XVI.)

It is generally admitted that our knowledge of the venous system is neither so accurate nor so complete as that of the arterial.

This deficiency is doubtless due to the greater difficulty experienced in the injection and dissection of the veins, and the much greater diversity observed in their form, arrangement, and course. No part of the venous system, however, can vie with the pelvic plexuses in the many obstacles which have to be overcome before a complete injection is attained, for the anastomoses of their constituent veins are manifold, the gas produced in them is difficult to contend with, and the valvular impediments found in them are great. These same plexuses are also unrivalled for real difficulty of venous dissection. This fact is readily appreciated, if we consider the extreme delicacy of their walls, the lack of a firm support, the minute calibre of their smallest veins, and the fineness and intricacy of their mesh.

Of the vesico-prostatic plexus, the celebrated anatomist J. Hyrtl has said—"Preparations of the venous plexuses of Santorini belong to the curiosities of an anatomical museum" (J. Hyrtl, *Handbuch der prak Zergliederungskunst*, p. 734).

It is upon this plexus—the vesico-prostatic—that the writer has more especially concentrated his attention, for the mere anatomical knowledge of the other pelvic plexuses is accurate—here only is it fallacious. The inexactness of our knowledge, as exemplified in the differences which may be observed in the various pictures of this plexus, can be accounted for, and will be reverted to immediately. A more important point than the normal course of the veins has, however, to be introduced.

The laws of the directions of the venous currents through this and the other pelvic plexuses, as established by due consideration of the direction and position of the innumerable valves found therein, have never been laid down. As far as the writer

can ascertain, the subject has been entirely overlooked, and the real value and influence which these current-regulators necessarily exert upon a part, through which large quantities of blood are momentarily passing, from which masses of blood are being frequently and suddenly displaced by the action of the viscera, has neither been justly estimated nor rightly appreciated. It is in the expectation of giving wider publicity to the subject, and thereby of gaining greater criticism, that the writer has ventured to publish briefly the results of a careful dissection of over fifty subjects only the normal anatomy being embodied in this paper.

In the investigation of the valves three points are to be insisted on.

1. No solid injection can be used.
2. Subjects should not be chosen above twenty-five years of age.
3. The veins must be slit up, to prove beyond doubt the existence and position of the valves.

1. It is absolutely impossible to ascertain the existence of valves in the veins, if any solid injection is thrown into them. To dissect uninjected veins necessarily increases the difficulty of investigation, but it is the only course adaptable.

2. Only young bodies can be used. This is a point of paramount importance. The advice given by Lenhossek is not good. He says—"To exhibit the venous system of the pelvis take a very *old* corpse because in it the veins are varicosed"¹ (they are easier to inject).

It is to the fact that for greater ease in preparation, bodies with such varicosity of the veins have been selected, injected, and depicted, that we owe our mistaken belief in the normality of that marked diversity thus observed in the form and arrangement of the vesico-prostatic plexus.

It will be found, however, that in subjects from the seventh month of intra-uterine life to the age of twenty-five, one broad type is clearly marked. Divergencies therefrom are few and trifling. After the latter age pathological changes may set in, greater stress may be thrown upon one or more particular points in the plexuses, involving enlargement of pre-existing venules

¹ Lenhossek, *Das Venöse Convolut der Beckenhöhle beim Manne*, 1871.

or even the formation of new venous channels, and the resulting venous plexus differs greatly from the normal arrangement.

3. A slight change of contour in the vein often simulates a valve; it is necessary, therefore, when valves are apparently found, to slit up the vein and confirm its presence. This is a rule reflecting some criticism upon the work of M. Houzé de l'Aulnoit (*Recherches anatomiques—sur les valvules des veines*, Paris 1854), the author who pointed out that valves exist in the veins at the base of the bladder. He describes his method of ascertaining the presence of a valve thus:—"If I could not see the valves I could always throw them into bold relief by a little pressure of the finger along the vein" (*i.e.*, by driving the contained blood against the valve). This method is not only crude, but extremely misleading, for often small blood clots will so block the finer veins as to simulate valves most markedly.

METHOD OF DISSECTION.

My earlier dissections were all made after the venous plexuses had been inflated, the knife cleaning the tense veins with certainty and ease. Coloured fluids were then thrown in, in a direction, which, in the living subject would be opposed to the normal venous current. The valves were easily seen through the thin-walled veins pouched by the force of the fluid. Their situation was then marked upon a plan previously taken of the dissection. Much labour was thus expended, each vesico-prostatic plexus and its connection often demanding more than a week's continuous work. I soon found it to be a quicker method to dissect out a small tract of a vein at a time, to clamp each end of the exposed piece, to make a diagram of it, and to inject it with fluid coloured with Berlin blue. If the injection was suddenly arrested, and a corresponding swelling at the site of the obstruction was observed, the vein was incised over the obstruction, and generally a valve exposed. It was then depicted.

For injecting the larger veins an ordinary Pravaz syringe with a small nozzle was used, but in the smaller, especially those in the intra-uterine subjects and in those of early childhood, the finest capillary glass tubes were absolutely necessary. The

greater part of the dissection of the finer meshes on the bladder had to be performed in direct sunlight.

RESULTS.

Consideration of the Valvular Arrangement of the Pelvic Venous System as a whole.—The venous bed in the pelvis, and the numerous tributary veins which enter it from below, may be roughly compared to a room with many approach-passages and with only one exit, the doors of these approach-passages opening inwards, permitting ingress, but preventing egress.

All the many veins which converge from the buttocks, genitals, and lower extremities to the pelvis, be it to the true or false divisions of that cavity, are valved at their entrance into it. These valves—some of the veins have two or even three sets—allow the venous blood to flow freely into the abdomen, but prevent its escape therefrom. Hence the abdomino-pelvic venous blood-pressure is entirely shut off from that of the lower extremities and genitals. The accuracy of closure and the constancy of position of these entrance-valves is most striking.

PROSTATIC SYSTEM.

The large dorsal vein of the penis which runs in the median groove of that organ is valved, often trebly so, just in front of the sub-pubic ligament.

After passing backwards beneath this structure it splits into two parts which clothe the sides of the prostate. Here it forms, with veins from the prostate and other tributaries, the *labyrinthus venosus* of Santorini.¹ The veins from this plexus or labyrinth travel backwards, receiving in their course veins from the sides and base of the bladder, and peri-rectal cellular tissue, and finally empty themselves into the internal iliac veins.

Valves.

Valves are present in all parts of this labyrinth of Santorini, or, as we shall term it, the vesico-prostatic plexus, from its

¹ Santorini, *Observat.*, p. 194.

commencement at the pubic arch to its termination in the internal iliac vein. These valves are in three groups. One group is found just behind the pubes, *i.e.*, at the commencement of the tract; another, a very constant and strongly made set, is placed at the termination of the tract guarding reflux from the internal iliac vein; a third set, less constant and apt to degenerate, is placed about the middle of the tract.

I would here briefly describe a valvular arrangement adjuvant to the post-pubic set of valves, which varies in strength according to the muscular development of the bladder.

Passing from the anterior and inferior surface of the bladder over the upper and anterior surfaces of the prostate are two thin muscles, the bundles of which seem to be generally in direct continuity with the anterior longitudinal fibres of the bladder. After crossing the various veins found on the prostate, *i.e.*, the post-pubic part of the vesico-prostatic plexus, each slip goes partly to be inserted into the pubes, beneath and outside the pubo-prostatic ligaments, and partly to blend with the innermost fibres of the anterior margin of the levator ani muscle of the corresponding side.

On contraction of the bladder, each plexus is compressed by the simultaneous contraction of this cross muscle, and hence regurgitation of the blood from the anterior inferior zone of the bladder, which is valveless, and from the rest of the plexus, now over-distended with the blood expressed into it by the contracting vesical wall, is prevented. We have as yet found no record of these—"the tourniquet muscles," as we may call them.

TRIBUTARIES OF THE VESICO-PROSTATIC PLEXUS.

Numerous veins enter this plexus—coming from the bladder, vesiculæ seminales, ureter, prostate, pubes, peri-rectal tissue, and anus.

With few exceptions every vein is valved at its entrance—often doubly valved. The plexus then is a large venous highway—the many paths leading into which permit of no backward passage—the blood passing of necessity directly into the inferior vena cava without attempting a circuitous route.

(a) With the exception of the anterior inferior zone of the

bladder, to be referred to immediately, most of the veins at the sides and base of that viscus are valved at their entrance into the vesico-prostatic plexus.

(b) The branch from the pudic vein and those from the peri-rectal veins are all powerfully valved. This fact is in direct opposition to the view generally taught, that the rectum can normally serve as a venous diverticulum to the bladder and prostate.

(c) Veins from the prostate gland entering the vesico-prostatic plexus are either *valved* or enter so obliquely from before backwards that their orifices guard them to a great degree from backward pressure.

Vesical Plexus.

This is, of all others, the most interesting, as it is, of all others, the most complete. There are three venous meshes—the submucous net (quite unvalved), the muscular, and the subperitoneal, both most carefully and intricately valved.

The Subperitoneal.—As regards their arrangement, it will be seen that the veins here have a very characteristic and purposeful course. On the anterior surface of the bladder a vertical vein commences at the summit, and after traversing the upper two-thirds, and draining it to that extent, it bifurcates. Each of the veins thus formed sweeps obliquely round the lateral surfaces of the bladder to empty itself more posteriorly into the vesico-prostatic plexus. We have named it the inverted Y-shaped vein. Thus, venous blood, from the entire upper two-thirds of the anterior surface, is forced on contraction—not into the plexus behind the pubes to arrest there the inrushing blood from the penis—but posteriorly and obliquely towards the termination of the plexus. The anterior inferior one-third of the bladder is drained by minute valveless veins into the post-pubic part of the plexus.

The veins from the lateral, posterior, and inferior parts of the bladder all open towards the posterior inferior angle of that viscus into the termination of the plexus, and all the veins here are stoutly guarded.

The veins on the posterior surface consist in two laterally

vertical veins, which are united by a cross branch. Their form thus resembles the capital letter H.

In describing the many valves found in the subperitoneal and muscular meshes, the bladder may be conveniently divided into three zones—a superior, middle, and inferior. These zones are again subdivided into anterior, lateral, and posterior divisions.

It will be found that in the normal bladder each of these zones (with the exception of the lower part of the anterior inferior zone) contains many valves, the constancy and strength of which is remarkable.

So evident is the design of directing the blood towards the posterior inferior angle—so carefully has venous pressure been minimised by the valves—that even the veins of the fat and cellular tissue which commonly surround and accompany the urachus to the umbilicus, are doubly, often trebly, valved—though here most minute—and the valves are so placed that they direct the blood from the region of the umbilicus into the valved H or inverted Y veins just described, and thence into the internal iliac vein.

The veins from the base include those from the third lobe of the prostate,—the vesiculæ seminales, the ampullæ of the vasa deferentia,—and pass for the greater part into the termination of the vesico-prostatic plexus, just before it empties itself into the internal iliac vein. They all are strongly valved.

The veins from the lower third of the ureter enter with the above, and are similarly strongly valved.

The Pudic Vein.

This has exactly the same valvular disposition which the writer proved as existing in the deep epigastric, and in every intercostal vein (Braune and Fenwick, *Die Venen der vorderen Rumpfwand des Menschen*, 1884).

There are three divisions—an internal iliac, a perineal, and a prostatic division. The middle or the perineal division receives tributaries, but, being valveless, allows the blood flowing into it to pass either into the vesico-prostatic plexus or into the internal iliac vein. Both the prostatic and internal iliac sections are valved at their terminations so as to prevent blood regurgitating into the pudic tract.

The internal iliac veins are formed by the fusion of several veins—gluteal, sacral, sciatic, obturator veins, and the vesico-prostatic plexus—all of which, except the tributary from the sacral plexus, are accurately valved.

A full account of the work will shortly be published; but from the above superficial description it will easily be appreciated how designedly and carefully the veins of the pelvis have been valved, and in such a manner as to reduce, in so far as is possible, the liability to congestion to which this, "the venous province par excellence," as Luschka calls it, must necessarily be exposed.

EXPLANATION OF PLATE XVI.

Fig. 1. Male, æt. 8. Right lateral aspect of bladder to show right postero-lateral angle. P, prostate; D, spot where water is found; E, F, G, veins to enter last part of vesico-prostate plexus.

Fig. 2. Same bladder. P, prostate; N, vesico-prostatic plexus; M, venous branch displaced somewhat downwards, receiving blood from peri-rectal tissue, and anastomosing with hæmorrhoidal vein; R, L, O mark similar branches; W, branch from internal pudic.

Fig. 3. Right postero-lateral angle of bladder of male, æt. 29. U, ureter; E, F, G, S, circumuretral ring of veins; E, vein from base of bladder; B, uretral vein.

Fig. 4. Right lateral aspect of bladder of male, æt. 38 (many valves atrophied). P, prostate; A, veins from perianal ring, extending from A upwards to vesico-prostatic plexus, is a pouched, valved vein; B, termination of internal pudic; R, S, inferior hæmorrhoidal branches; E, branch from bulb; D, D', peri-rectal veins; F, F', mid-plexial valves, G, isolated post-pubic valve; M, N, N', terminal valves; I, L, internal iliac.

Fig. 5. Bladder of male, æt. 75. P, prostate, with contracted orifice of urethra, c; M, the tourniquet muscles cleaned as they cross the plexus; C, D, E, the inverted Y vein.

The diagram shows the antero-inferior zone valveless.

NOTES ON SOME UNUSUAL VARIATIONS IN HUMAN ANATOMY. By ARTHUR THOMSON, M.B., *Demonstrator of Anatomy, University of Edinburgh.*

I. VASCULAR.

1. *Case of origin of the superior thyroid, lingual and facial from the common carotid by a common trunk.*—The common trunk of these different vessels arose from the common carotid, a little above the level of the *lower* border of the thyroid cartilage, three-quarters of an inch below the level of the division of the common carotid into internal carotid, and the trunk which gave origin to the remaining branches of the external carotid.

The branches were arranged as follows :—

(a) Immediately after its origin it gave off the superior thyroid, which, passing transversely under the anterior belly of the omo-hyoid and sterno-hyoid, supplied these muscles as well as the thyro-hyoid. Continuing downward, under cover of the sterno-thyroid, it was distributed to the thyroid body.

(b) The superior laryngeal artery passed inwards, forwards, and upwards over the inferior constrictor, and beneath the sterno-hyoid and thyro-hyoid to the upper border of the thyroid cartilage, at which point it pierced the thyro-hyoid membrane.

(c) About three-quarters of an inch above its origin, the trunk common to these vessels then divided into the lingual and facial arteries, this point corresponding to the level at which the common carotid usually bifurcates.

The lingual artery passed upwards and forwards towards the great cornu of the hyoid bone. In this part of its course it lay upon the inferior and middle constrictor muscles, separated from the former by the superior laryngeal nerve. At the great cornu of the hyoid bone the artery then passed forward parallel to the upper border of the bone, at first lying superficially upon the surface of the hyo-glossus, but ultimately piercing its fibres to assume a normal position. In its course the artery did not come into relation with the ninth nerve until it lay on the surface of the genio-hyo-glossus, anterior to the anterior border of the hyo-glossus.

(d) As the facial passed upward it lay superficial to the external carotid artery, but separated from it by the inferior palatine artery, which in this case was derived from the external carotid; prior to passing beneath the posterior belly of the digastric and stylo-hyoid it was crossed by the ninth nerve.

Its subsequent course was normal.

It did not give off the inferior palatine artery, and no trace could be found of its tonsillar branch.

The ascending part of the external carotid was normal, in so far as it sprang from a trunk which commenced at and occupied the normal position of the external carotid artery, as usually described. This branch, entering the substance of the parotid gland, divided into internal maxillary and temporal arteries.

Instances of such a disposition of these arteries are rare. Quain's¹ case, figured in plate xiii. fig. 8, differs materially from the present, as in his case there is an entire absence of the internal carotid. I have failed to find any record of a precisely similar condition.

Surgically the case is of importance, as the operator might be thrown off his guard, and assume that the arrangement of the vessels as seen in the dissection was due to an unusually low bifurcation of the common carotid into external and internal carotid arteries.

2. *Case in which the artery to the corpus cavernosum penis was derived from an irregular obturator artery.*

The obturator artery arose in common with the deep epigastric artery. The obturator trunk passed down behind the horizontal ramus of the pubes internal to the crural ring, and, reaching the upper border of the thyroid foramen, it then escaped from the pelvis over the margin of the pelvic fascia; and on the removal of the obturator externus muscle and thyroid membrane it was seen breaking up into a number of branches on the superficial aspect of the obturator internus muscle. One of these branches, passing transversely inwards, pierced the fibres of the obturator internus muscle close to the descending ramus of the pubis, and, becoming encased in a sheath of fascia derived from the parietal

¹ Quain, *Commentaries of the Arteries*, p. 100, pl. xiii. fig. 8.

pelvic fascia, was carried forward to the point of attachment of that fascia to the pubic arch, it lay between the layers of the triangular ligament for a short distance, and then, piercing the anterior layer of that ligament, entered the substance of the crura of the penis.

There was a similar disposition on both sides.

An almost identical condition is figured in Quain, plate 1 fig. 1. In the present example, however, the dorsal artery, the penis was derived from the external iliac close to its termination, and passed downward and inward much in the position of the superior external pudic, to end on the dorsum of penis.

II. NERVOUS.

1. There occurred in the rooms an instance in which a cutaneous branch of the first intercostal branch was peculiar; in the axilla it was joined above by a nerve from the cord formed by the eighth cervical and first dorsal. This unusual branch passed down behind the first paraxillary artery resting on the highest digitation of the magnus. After its union with this nerve the lateral branch of the first intercostal joined the lateral cutaneous of the second intercostal to form the inter-costo-humeral.

2. Case in which the first rib was pierced by a foramen transmission of a branch of the first dorsal nerve.

On the right side, as the first dorsal nerve lay by anterior border of the scalenus medius and the pleura, it gave off a branch which ran downwards and forwards, close to the anterior border of the scalenus, that muscle passed to be attached to the rib. The branch lay close to the upper border of the first rib near the tubercle, and then disappeared behind the rib, lying and the parietal pleura. It then passed obliquely and forwards so as to reach the foramen which rib 1 $\frac{1}{4}$ inches external to the costo-chondral. Having passed through this canal it was distributed as follows:—About 1 inch after its appearance the

it split up into two portions, one of which joined the internal cutaneous nerve, the other was distributed to the skin over the insertion of the latissimus dorsi muscle. On the left side of the body, just before this branch of the first dorsal nerve entered the foramen in the rib, it was joined by a branch from the second intercostal nerve, which arose from that nerve close to the posterior extremity of the second intercostal space, and passed obliquely upwards and forwards across the second rib and first intercostal space to its point of junction with the above.

3. *Irregularity in the origin and nerve supply of the adductor longus.*

In this case the adductor longus had a wide origin extending along the ilio-pectineal line for about an inch. It almost appeared as if the superficial fibres of the pectineus had become blended with the adductor longus.

A small nerve was seen to cross behind the femoral vessels and through the substance of the pectineus muscle, to which it gave branches, and to end in the adductor longus. On being traced upwards the nerve was found to pass beneath Poupart's ligament external to the femoral sheath, and was then seen to lie upon the surface of the psoas muscle in very close relation to the tendon of the psoas parvus. It then entered the substance of the psoas magnus about 2 inches above Poupart's ligament, and was subsequently found to be an offset of the third lumbar nerve. In addition, a large branch from the superficial division of the obturator nerve was found entering the deep surface of the adductor longus muscle.

4. *Accessory obturator nerve joined by branch from anterior crural supplying the adductor longus.*

In this example the accessory obturator took origin from the third lumbar. In the thigh this nerve pierced the pectineus, and previous to entering the substance of the adductor longus muscle, which it in part supplied, it was joined by a branch from the anterior crural nerve, which reached it by passing behind the femoral vessels. On raising up the adductor longus a large branch was seen entering its deep surface from the superficial position of the obturator nerve.

Three distinct branches were traced from the anterior crural nerve to the pectineus muscle.

III. MUSCULAR.

Unusual insertion of the brachialis anticus into the orbicular ligament and capsule of the elbow-joint.

The upper and internal fibres of the muscle were inserted as usual into the anterior surface of the coronoid process of the ulna.

The fibres, which arose from the lower part of the anterior surface of the shaft of the humerus, and from the external inter-muscular septum, were more oblique in direction, and lay under cover of the fibres inserted into the ulna.

The deeper fibres were connected with a bony spicule about $1\frac{1}{2}$ inch long.

This process in its general appearance resembled the great cornu of the hyoid bone. It lay obliquely on front of the joint, its lower end being connected with the anterior surface of the orbicular ligament, and also with the anterior portion of the capsule, which, in this instance, was much stronger than usual. The upper extremity of the bony process lay superficial to the coronoid fossa.

On the reflection of the muscle the deep surface of this osseous style was concealed by the tendinous and muscular fibres inserted into its deep surface.

The two insertions of the muscle were united by a tendinous arch, into which the intermediate muscular fibres were inserted.

It will thus be seen that this arrangement cannot be classed in the variations recorded by Testut,¹ who enumerates five modes of insertion (1) into the ulna; (2) into the radius; (3) into the tendon of the biceps; (4) into the antibrachial aponeurosis; (5) into the synovial membrane of the elbow-joint; the latter, according to Testut, representing on the front of the elbow the sub-anconeus as seen posteriorly.

¹ *Les Anomalies Musculaires chez l'homme*, page 401.

Anatomical Notice.

ABSENCE OF EXTENSOR CARPI ULNARIS AND PRESENCE OF AN ACCESSORY SURAL MUSCLE. By Professor W. TURNER.

A. Absence of Extensor Carpi Ulnaris.

IN the month of January 1885 two of my pupils—Messrs T. B. Whitelaw and R. A. Fleming—directed my attention to the left fore-arm of a male subject which they were engaged in dissecting. When the aponeurosis on the back of the fore-arm was reflected, no muscle was seen in the region customarily occupied by the extensor carpi ulnaris, so that the origins of the extensores secundi internodii and indicis were at once seen. The aponeurosis of the fore-arm, where it was attached to the posterior border of the shaft of the ulna, was strong, and a narrow band in this fascia, somewhat stronger and more opaque than the rest, extended longitudinally down the limb parallel to the ulna. Immediately above the styloid process of the ulna, this band isolated itself from the fascia, and entered the groove on the back of the ulna, in which the tendon of the extensor carpi ulnaris ought to have been lodged. It occupied the position of that tendon, but was only about one-sixth its size, though the ulnar groove was of about the usual magnitude. It was contained in a compartment under cover of the posterior annular ligament. After emerging from this groove it ran downwards, and at the same time became about twice as thick, and reached the base of the fifth metacarpal bone, to which it was attached. It also gave a process to the fascia on the back of the carpus.

This arrangement exhibited a condition in which the muscular belly and tendon of origin of an important muscle had not been developed, and had been replaced by a slender fibrous band, fused with the aponeurosis of the fore-arm, but the tendon of insertion had been formed, and with it the groove in the ulna had been produced. It is an illustration of the conversion of a muscle into fibrous tissue, of which so many interesting examples have been given by Mr J. Bland Sutton in the present number of this *Journal*.

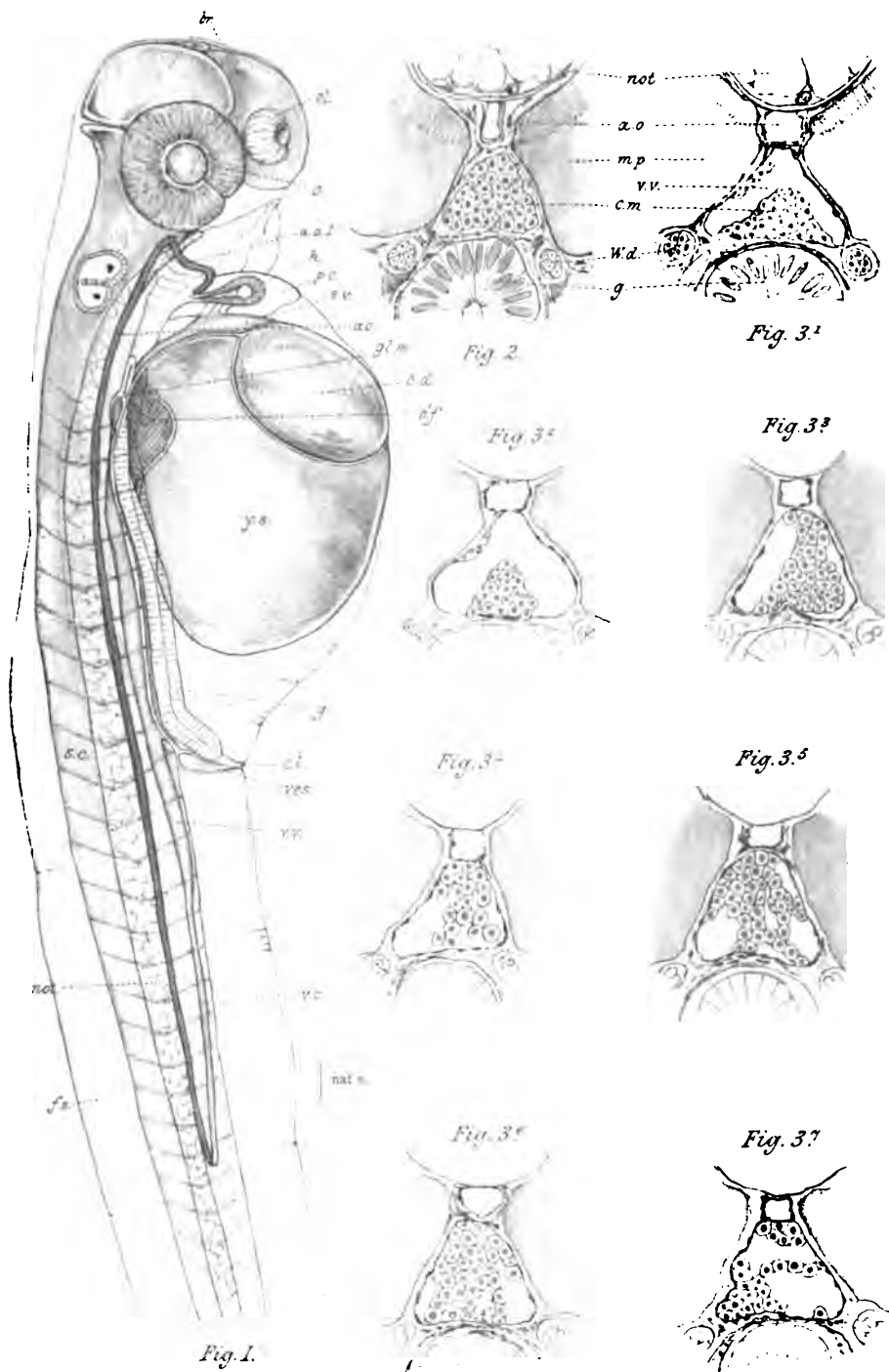
At the time when I recorded this anomaly in my dissecting-room notebook, I was under the impression that no similar case had been noticed, as no mention is made of such a specimen by Professor Macalister in his important *Catalogue of Muscular Anomalies*, or by M. Testut in his most valuable work, *Les Anomalies Musculaires chez l'Homme*, published last year. A few days ago I received from my correspondent, Professor Gruber of St Petersburg, a copy of a paper which he has just published in *Virchow's Archiv*, vol. xcix. p. 478,

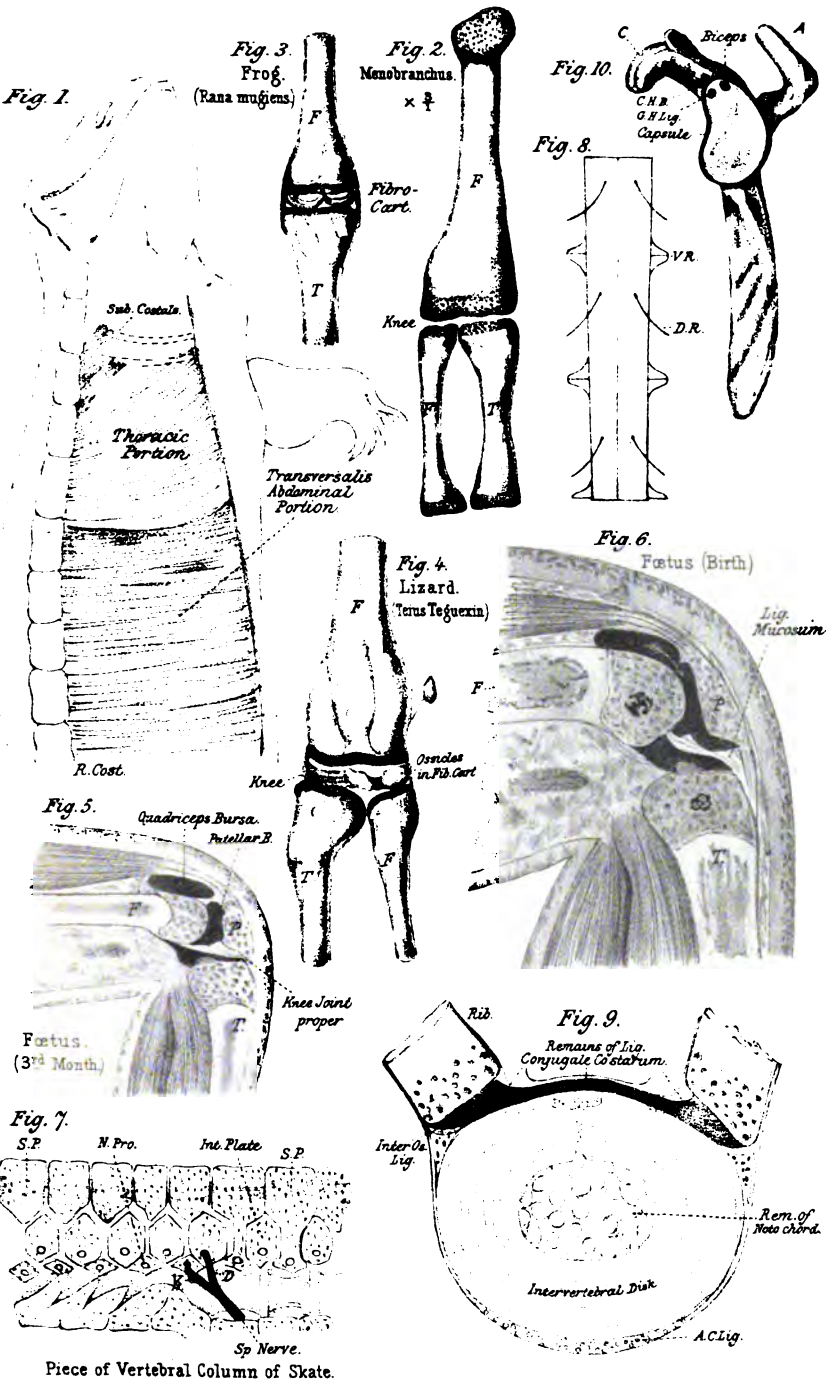
in which he describes a specimen almost identical in its arrangements with the case above recorded. He observed it in February 1883, in the left arm of a man, and speaks of it as a quite new example amongst muscular anomalies.

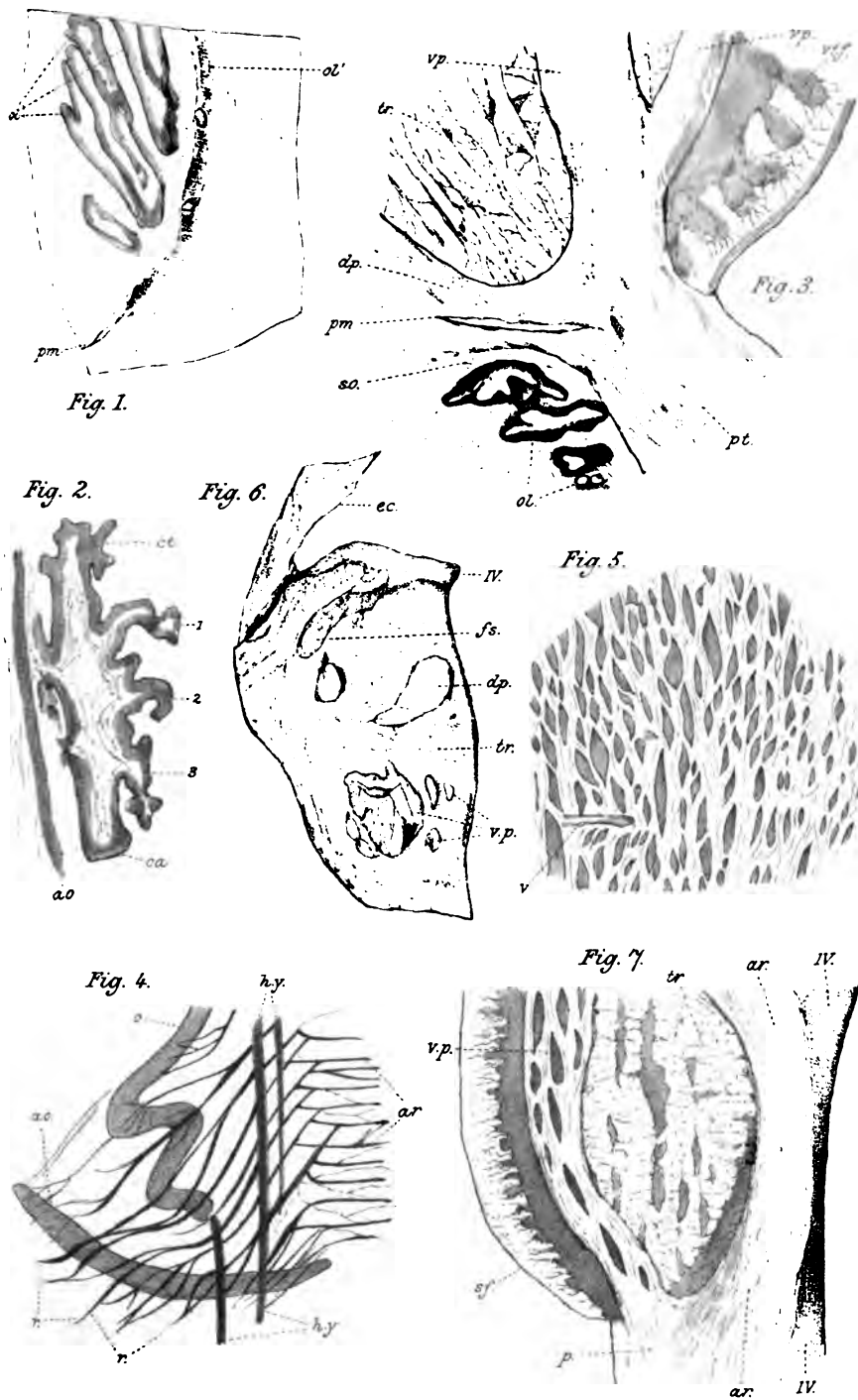
B. *Presence of an Accessory Sural Muscle.*

During the present winter, in the back of the right thigh of a male subject dissected by Mr Frederick Watson, I observed that the long head of the biceps gave origin about the middle of its fleshy belly to a muscle, a little more than one inch in circumference. This accessory muscle descended superficial to the internal popliteal nerve, and about the level of the head of the tibia terminated in a slender tendon, which occupied the groove between the two heads of the gastrocnemius, and about the level of the lower end of the fleshy bellies of that muscle it began to fuse with the posterior aspect of the gastrocnemius tendon, and ultimately became a part of the tendo Achillis. There was no corresponding arrangement on the left side.

This variation, although very uncommon, is not so rare as the one first noted in this communication, for cases have been recorded by Kelch, Wenzel Gruber, and W. D. Haliburton (*Jour. of Anat. and Phys.*, vol. xv. p. 296, 1881), which closely resemble the above specimen.









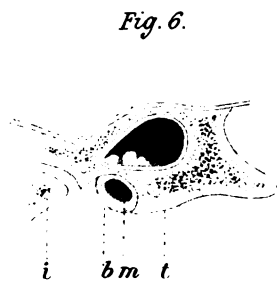
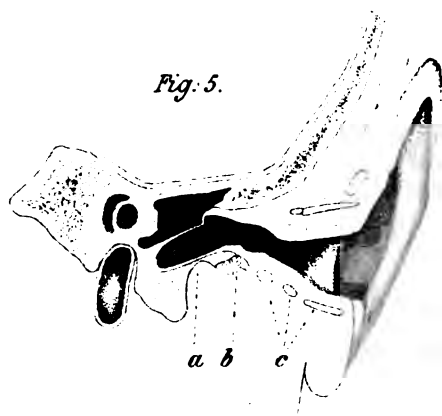
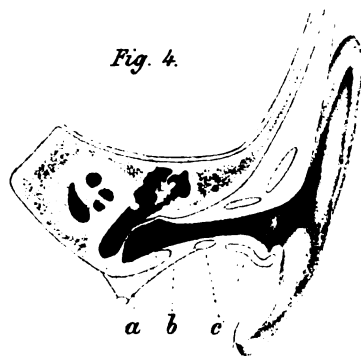
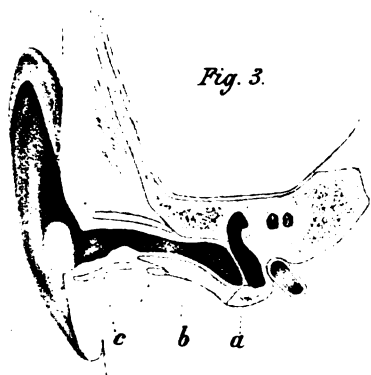
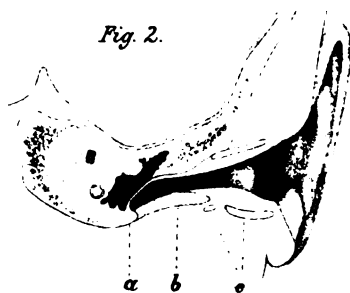
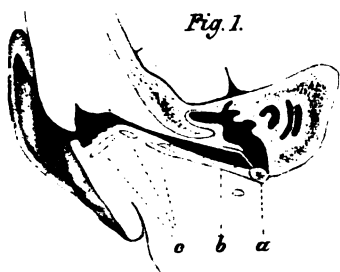




Fig. 1.

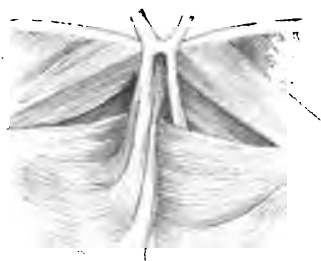


Fig. 2.



Fig. 3.



Fig. 4.



Fig. 5.

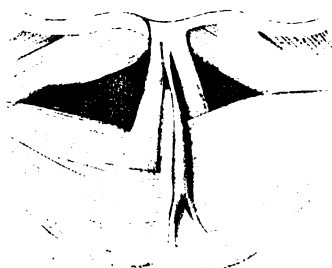
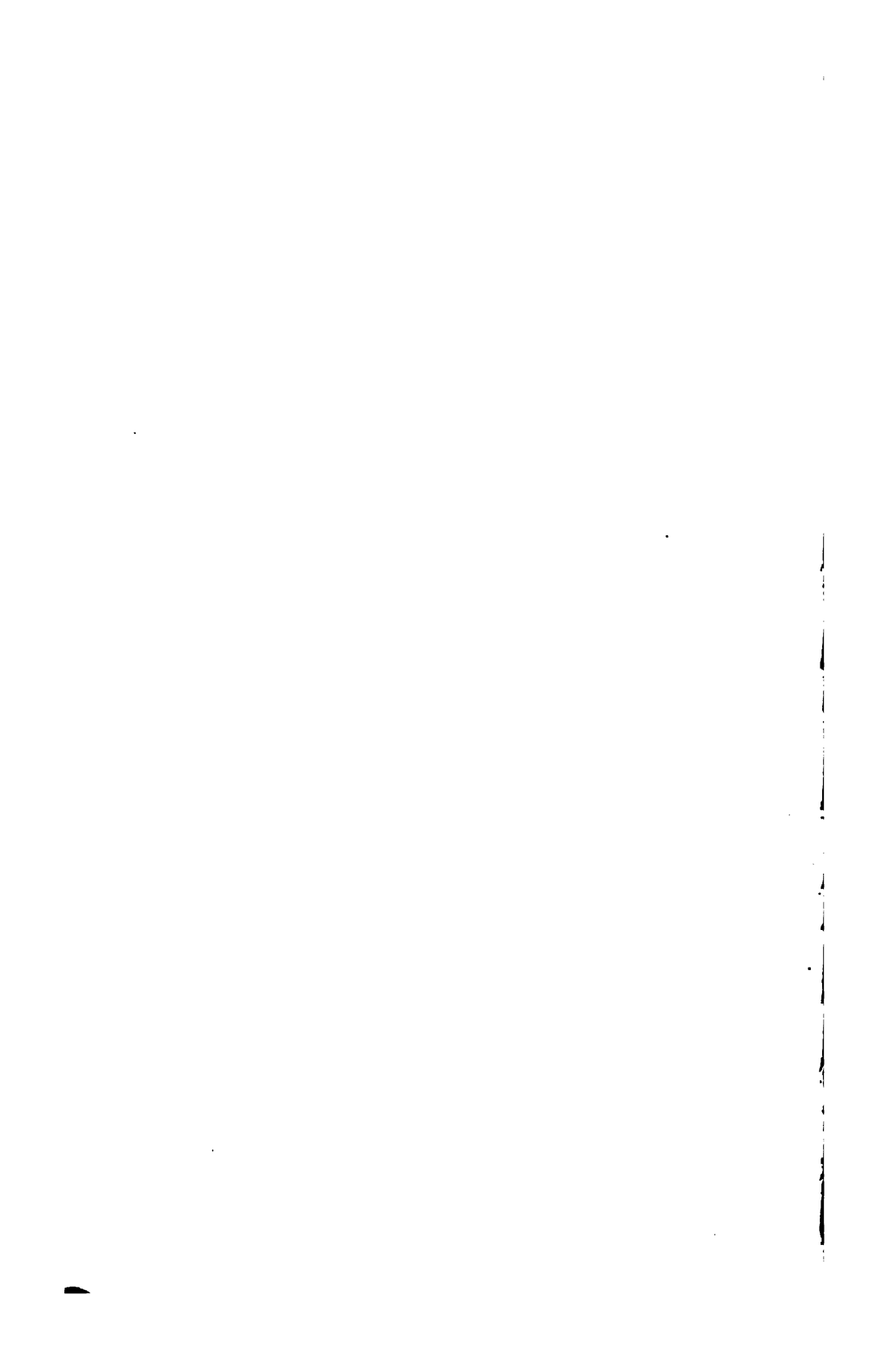


Fig. 6.



Journal of Anatomy and Physiology.

AN ACCOUNT OF SOME RECENT EXPERIMENTS ON
THE EFFECTS OF VERY LOW TEMPERATURES ON
THE PUTREFACTIVE PROCESS, AND ON SOME
VITAL PHENENOMA.¹ BY J. J. COLEMAN, F.C.S., F.I.C.,
and Professor JOHN G. M'KENDRICK, M.D., LL.D., F.R.S.

IN recent years many experiments have been made as to the effects of high temperatures on micro-organisms, with the result of showing that while exposure to temperatures of from 122° to 140° F. kills many of such organisms, some, especially the spores of bacilli, require exposure to the heat of boiling water for as long as half an hour. It is stated by Klein that "no spores survive exposure to a temperature of 120° C." (248° F.).² The question naturally arose as to whether or not it might be possible to destroy such organisms by cold, and various observers have attempted to answer it. Thus, before 1872, we find Dr Ferdinand Cohn³ stating that he had subjected bacteria to low temperatures without destroying their activity. He gives the temperatures as follows:—Exposure for 12 hours 30 minutes to a temperature 0° C.; for 1h. 30m. to -16° C.; for 1h. 45m. to -17° C.; for 3h. 30m. to -18° C.; for 4h. 30m. to -18° C., for 5h. to -17°·5 C.; for 6h. to -14° C.; and for 7h. 30m. to -9° C.⁴ He produced the cold by freezing mixtures, and the lowest temperature he obtained was -18° C. = 0° F.

¹ Read before the Philosophical Society of Glasgow, 4th March 1885.

² Klein's *Micro-Organisms and Disease*, 1884, p. 35.

³ Cohn's *Beiträge zur Biologie der Pflanzen*, 1870, Zweites Heft, p. 221.

⁴ To convert F.° to C.° subtract 32, multiply by 5, and divide by 9. To convert C.° into F.° multiply by 9, divide by 5, and add 32.

Klein¹ states that "freezing destroys likewise most bacteria, except the spores of bacilli, which survive exposure to as low a temperature as -15° C., even when exposed for an hour or more." Again, in another place² he says—"Exposing the spores of anthrax-bacillus to a temperature of 0° to -15° C. for one hour did not kill them."

In 1884 a remarkable series of experiments were described to the French Academy by MM. R. Pictet and E. Yung.³ These observers sealed up in small glass tubes fluids containing various kinds of microbes, and placed them in a wooden box. The box was in the first place submitted for 20 hours to a cold of -70° C., produced by the evaporation of liquid sulphurous acid *in vacuo*. The box was then surrounded by solid carbonic acid for 89 hours, and a cold of from -70° to -76° C. was thus obtained. Finally, the box was subjected for a third period of 20 hours to a cold produced by the evaporation of solid carbonic acid *in vacuo*—the temperature being estimated at from -76° to -130° C.—that is, a minimum temperature of 202° below zero Fahrenheit. They sum up by stating that the organisms were acted on by a cold of -70° C. for 109 hours, followed by a temperature of -130° for 20 hours. The organisms tested were *Bacillus anthracis*, *B. subtilis*, *B. ulna*, *Micrococcus luteus*, and a micrococcus not determined. *Bacillus anthracis* retained its virulence when injected into a living animal. The vitality of the others was not affected. Experiment showed that, whilst cold seemed to kill some of the micrococci, a great number resisted it. Yeast showed no alteration under the microscope, but it had lost its powers of fermentation. Vaccine lymph exposed to the low temperatures did not produce a pustule on the left arm of an infant, whilst another sample of the same lymph introduced into the right arm of the same child produced a pustule. Pictet and Yung conclude, from their experiments, that, in the conditions of cold indicated, many of the lower organisms were not destroyed.⁴

¹ Klein, *Micro-Organisms*, p. 35.

² Klein, *op. cit.*, p. 73.

³ *Comptes rendus*, tome xviii. No. 12 (24th March 1884), p. 747.

⁴ In a letter to Dr M'Kendrick, Professor Arthur Gamgee states, that some months ago he exposed putrescible fluids to moderate degrees of cold without thereby preventing putrefaction, and that he abandoned the research as unlikely to lead to any important result with the temperature he had at command. It is

Prior to becoming acquainted with these remarkable researches, we had begun the investigation, the results of which will now be shortly communicated.

The difficulty of experimenting upon the effects of low temperatures upon various substances has been much lessened by the practical introduction of cold air machinery for technical purposes, described in a paper read by Mr Coleman to the Institute of Civil Engineers in February 1882. These machines, in an ordinary way, supply streams of atmospheric air cooled to about 80° below zero F. (— 63° C.), but, by certain modifications they can be adjusted to deliver the air cooled much lower, and, in point of fact, to as low temperatures as have yet been produced in physical researches.

For the purposes of these experiments a machine, worked by a gas motor engine, capable of delivering 30 cubic feet of air (.84 cubic metre) per minute, has been employed, the cold air being made to pass upward in a square vertical shaft of wood, in the sides of which were apertures regulated by valves, and by means of which about a dozen chambers, each of 3 cubic feet capacity (.84 cubic metre), could be maintained at any particular temperature desired. These temperatures were carefully taken by an absolute alcohol thermometer, made by Negretti & Zambra, and checked by a special air thermometer devised by Mr Coleman.

The experiments consisted in exposing for hours to low temperatures putrescible substances in hermetically sealed tins or bottles, or in flasks plugged with cotton wool; the tins or flasks were then allowed to thaw, and were kept in a warm room, the mean temperature of which was about 80° F. (27° C.); they were then opened and the contents submitted to microscopical examination with magnifying powers of from 250 to 1000 diameters. The general results are as follows:—

1. Meat in tins (4½ inches in diameter, and 1 inch in depth), exposed to 80° below zero F. (— 63° C.) for 6 hours underwent putrefaction with generation of gases.

2. Whilst these experiments were going on, comparative ex-

also stated in Landois' *Physiology*, translated by Stirling, vol. i. p. 456, on the authority of Frisch, that "bacteria survive a temperature of — 87° C.; yeast even — 100° C."

periments were made with tins and bottles containing meat, but not exposed to cold. Under such circumstances, the effects of storing them in the warm room for even the short period of a fortnight, was to develop such large quantities of extremely foetid gas, and very active bacteria and vibrios, that we had no doubt whatever but that exposure to a cold of 80° below zero (63° C.) had checked their development to some extent in the subsequent exposure to a warm temperature.

3. On the 24th of December 30 samples of fresh meat were placed in 2 oz. white glass phials. These were carefully corked with corks previously steeped in mastic varnish, and the necks of the corked bottles were then immersed in melted sealing wax. These bottles were divided into five sets, and marked A, B, C, D, and E, and they were treated as follows:—

A. 6 samples were exposed to zero F. (-17° C.) for 65 hours.

B. 6	„	„	-20° F. (-29° C.)	„
C. 6	„	„	-30° F. (-34° C.)	„
D. 6	„	„	-40° F. (-40° C.)	„
E. 6	„	„	-80° F. (-62° C.)	„

These experiments ended on 28th December. On the 29th one bottle from each group was again exposed to 80° F. (-63° C.) for 6 hours, then again frozen for 6 hours at -80° F. (-63° C.) The whole of those were removed to the room, but in the meantime it was noticed that at temperatures below zero, and particularly so low as -80° F. (-63° C.), the meat assumed a peculiar dirty-brown appearance. In the course of a few hours, however, the whole of the samples assumed at normal temperatures the well-known reddish colour of meat. In all cases, however, in the course of 10 or 12 hours after removal to the warm room, signs of putrefaction were visible, and in the course of a few days the putrefactive process was fully established. It is important to notice that the temperature reached in these experiments, namely, from -70° to -80° F. (-56° to -63° C.), is nearly the minimum degree of cold hitherto observed in Polar expeditions. (*See Note.*)

4. It is well known that freezing muscle taken from a newly killed animal prevents the coagulation of muscle-plasma, and that the plasma can, on partial thawing, be squeezed out of the

muscle and allowed to coagulate. It occurred to us that if muscle were suddenly exposed to extreme cold, before cadaveric rigidity had set in, some change might be observed in the putrefactive process. Accordingly, a rabbit was instantaneously killed, portions of its muscles were at once placed in stoppered bottles and transferred to the cold chamber, then having a temperature of about -80° F. They were kept there for 10 hours; then allowed to thaw partially in the cold chamber, whilst the cold air machine was not at work; then again frozen for 12 hours; and finally transferred to the warm room. In these circumstances, they underwent rapid putrefaction. The samples seemed to be more moist than other specimens of ordinary butcher meat, and they certainly underwent more rapid putrefaction.

5. A further set of experiments with meat was carried out, in which the samples were continuously exposed to a temperature of from -90° to -120° F. (-83° C.) for 100 consecutive hours, the bottles were then removed to the warm room, with the result that in 10 or 12 hours the putrefactive process seemed to be fully established.

5a. It has been shown by Pasteur¹ that if putrescent or fermenting substances are sealed up in a comparatively small space containing air, the processes are arrested when all the oxygen has been used up, and the products of putrefaction may undergo no further alteration. In these circumstances, in such experiments as ours, the apparent arrest of putrefaction in sealed vessels might have been attributed to the action on the organisms of the low temperature to which they had been exposed, instead of to the real cause—the removal of all the oxygen from the confined air. To meet this difficulty we saw the importance of testing the effect of cold on putrescible substances placed in test tubes and flasks firmly plugged with cotton wool, through which there might be a free play between the gases in a tube or flask and the surrounding atmosphere. Nor was it necessary in such experiments to sterilise the cotton wool by heat, as must be done in all researches on the effects of high temperatures, because if a low temperature were fatal to micro-organisms, it would kill those in the cotton wool as well as

¹ *Comptes rendus*, lvi. 734-1189. See also article "Fermentation," Watt's *Dictionary of Chemistry*, first supplement, p. 612.

those in the putrescible substances. Many experiments were made with tubes and flasks stopped with cotton-wool plugs instead of being hermetically sealed, but there was no difference in the general result.

6. Six flasks were filled with fresh urine, and plugged with cotton wool, on the 10th of December. The first one plugged with wool was exposed to the temperature of the engineering shop where the experiments were carried on (about 50° F.), and on the 13th the urine was muddy. On the 18th it was found to be swarming with bacteria and vibrios. The second was exposed for 8 hours to zero F.; on the 13th it showed slight muddiness, and on the 18th it was swarming with bacteria. The third was exposed to a temperature of -10° F. for 8 hours, and on the 18th it was also swarming with bacteria. The fourth was exposed to -20° F. with the same result. The fifth was exposed to -30° F. with a like result. The sixth was exposed to -80° F., and it did not become muddy until the 22nd, that is, 12 days after the beginning of the experiment. These results showed that freezing at very low temperatures delayed the appearance of the alkaline fermentation due to organisms, but a temperature of -80° for 8 hours did not sterilise the urine.

7. Samples of fresh milk exposed to temperatures of from zero to -80° F. for 8 hours curdled, and showed the well-known *Bacterium lactis*, and, so far as could be observed, freezing did not delay the process after the flasks were kept at a temperature of about 50° F.

8. Samples of Prestonpans beer (containing about 2 per cent. of alcohol) were similarly treated. Exposed to the air of the shop, a scum of torulæ made its appearance in three days. Freezing undoubtedly delayed the appearance of these in flasks plugged with cotton wool, and the delay corresponded to the fall of temperature, so that the sample exposed to -80° F. did not show the scum for twenty-two days after its removal from the cold chamber. Still it could not be said that this degree and duration of cold sterilised the fluid.

9. Samples of sweet ale behaved in a precisely similar manner.

10. Samples of meat juice, made by boiling lean meat, filtering and carefully neutralising, were also operated on, both in

flasks hermetically sealed and having the necks stuffed with cotton wool. Exposed to temperatures of from zero to -80° F. for 8 hours, all of these in due time showed, under the microscope, numerous bacteria, but the freezing process undoubtedly delayed their appearance, and this was most marked in the samples exposed to the lowest temperatures.

11. Samples of neutralised vegetable infusion behaved in a similar way.

12. Many experiments were made with putrefying fluids, full of bacteria and other micro-organisms. The method followed was to examine the fluid with the microscope, and to note the appearances of the organisms. These portions of the fluid were placed either in a flask plugged with cotton wool or in a hermetically-sealed flask, and exposed to the lowest temperature attainable, namely, -120° F. In one set of experiments such organisms were exposed to -120° F. for 100 consecutive hours. The thawed fluid was again examined microscopically, with the result of showing that the organisms were motionless. Still it could not be asserted that they, or at all events their spores, were dead, as, after exposure to a temperature of 80° F. for a few hours, the fluid was found to be again teeming with organisms in active movement. The conclusion arrived at was that such prolonged exposure to cold as we could give did not kill them, or, at all events, it did not kill them all, probably leaving spores unaffected.

13. We also attempted, by *repeated* freezings and thawings, to kill micro-organisms, as it was conceivable that cold might kill the adults only, leaving the spores unaffected. If, then, the spores were killed as they approached maturity, and before they had produced new spores, we might be able to sterilise the fluid. All our attempts in this direction were unsuccessful.

14. Experiments were also made with gelatinous infusions of meat, to which grape sugar had been added. Exposure to low temperatures and thawing did not destroy the gelatinous character of the substance, but putrefaction was not prevented. Such gelatinous masses, after exposure for 100 consecutive hours to -120° F., quickly liquefied and gave off gas after remaining 15 to 20 hours in the warm room.

15. It is a striking consideration that freezing at low tempera-

tures makes a mass of organic matter solid throughout, so that it can only be broken to pieces by violent blows of a hammer. It has then a fractured surface like a piece of rock. Still, when such a mass—say a piece of muscle—is thawed, its microscopical structure seems to be unaltered. All that can be said is that it is moister than ordinary fresh muscle. It is probable, therefore, that the bodies of micro-organisms are also frozen solid, and yet they apparently may live for a long time in this condition. One cannot suppose that in these circumstances any of the phenomena of life take place; the mechanism is simply arrested, and vital changes may again occur when the conditions of a suitable temperature return. Such considerations led us to examine whether any of the vital phenomena of higher animals might be retained at such low temperatures. We ascertained that a live frog may be frozen quite solid throughout by a temperature of from -20° F. to -30° F. in about half an hour. On thawing slowly in two instances, the animal completely recovered. When kept in the cold chamber longer than half an hour, the animal did not recover, but the muscles and nerves were still irritable to electricity, responding to weak induction shocks. Reflex action, however, was abolished. In two cases frogs were exposed for 20 minutes to a temperature of -100° F. On thawing they did not recover, but the muscles still feebly responded to electrical stimulation, showing that their irritability had not disappeared. The probability is that longer exposure to this temperature, or exposure for a shorter time to a lower temperature, would destroy muscular and nervous irritability, but it is a striking fact that irritability can survive to any degree a transition through a state of solidity produced by cold.¹

16. One experiment was performed on a warm-blooded animal—a rabbit. Before the experiment, the temperature of the rectum was $99^{\circ}2$ F., pulse 160 per minute, respirations about 45 per minute. At 10.30 A.M., it was placed in the cold chamber, the thermometer of which stood at -93° F. At 11 A.M. it was removed for a minute or two; it did not seem to be affected, but the temperature of the rectum was now $94^{\circ}2$, a

¹ Kühne observed that a frozen frog's muscle will contract after thawing, but the temperature he reached, was not low

fall of 5° in half an hour. It was then reintroduced into the cold chamber, the temperature of which was read off at -100° F. It was taken out at 12 noon; it seemed to be comatose; reflex action was abolished: there were jerking movements of the limbs; its rectal temperature was now 43° F., a fall of 51° during the hour; its pulse was 40 per minute, being a fall of 120; and its respirations were barely perceptible. It was placed in a warm place, and began slowly to recover. In 15 minutes its temperature had risen to 72° F., in 10 minutes more to 89° F. Its pulse beats when removed from the chamber were 40 per minute, in 15 minutes they had risen to 60 per minute, and in 15 minutes more to 100 per minute. The animal completely recovered. When removed from the chamber at 12 noon, although reflex action was abolished, the muscles were still irritable to electrical stimulation, and on placing the wires over the sciatic nerve, without cutting the skin, strong spasms of the muscles of the leg were caused, showing that the nerve was still irritable. It follows, therefore, that some of the effects of the extreme cold were due to inactivity of the nerve centres. Consciousness and reflex action were abolished, owing to inactivity of the grey matter of the encephalon and of the spinal cord.

The effect of the extreme cold on the warm-blooded or homoiothermal animal, as contrasted with its effect on the cold-blooded or poikilothermal animal is very striking. The cold-blooded frog became as hard as a stone in from 10 to 20 minutes, and the temperature of its body was probably the mean temperature of the chamber; the warm-blooded animal produced in itself so much heat as enabled it to remain soft and comparatively warm during exposure of an hour's duration to -100° F. Still its production of heat was unequal to make good the loss, and every instant it was losing ground until, at the end of the hour, its bodily temperature had fallen about 56° F. below its natural temperature. Had it been left in the chamber long enough, its bodily temperature would have fallen until it reached the temperature of the cold chamber, and it would then have become as hard as the frozen frog. It is remarkable, however, that even at the end of an hour's exposure to -100° F., its bodily temperature was 143° above -100° F. As blood freezes

and the hæmoglobin crystallises at about 25° F., had the temperature of the body fallen below that point, the animal would not have recovered, as its blood would have been destroyed.

We have only to add that, while the results attained in this research are mainly negative, they are a contribution to our knowledge of some of the conditions on which the vitality of micro-organisms depend. It is clear that albuminous solids and solutions of albuminous matter cannot be sterilised by prolonged exposure to very low temperatures, and that therefore any hope of preserving meat by permanently sterilising it by cold must be abandoned. Still, as it seems improbable that no degree of cold can kill micro-organisms, we hope to renew our attempts, in which we will use, as far as possible, organisms isolated by cultivation, and these will submit to still lower temperatures than have yet been reached in biological experiments.

NOTE.—With reference to the statement in paragraph 3, p. 4, we have been favoured with the following remarks by Mr Alexander Buchan, the eminent meteorologist, to whom we applied for information:—"So far as I am aware, or can discover, the temperature of - 73°·7 F., registered on board the *Alert* in March 1876, is the lowest temperature yet observed anywhere in the free atmosphere. The lowest *mean monthly* temperature known is - 55°·8 F. for January, at Werchojansk (lat. 67°·34' N, and long. 133°·51' E), in north-eastern Siberia." It is possible that one or more of the individual observations that make up this low mean may have given a reading lower than - 73°·7 F.

ACCESSORY LOBE TO THE LEFT LUNG. By LAURENCE HUMPHRY, M.B., *Assistant Physician to Addenbrooke's Hospital, Cambridge.* (PLATE XVII.)

IN making a *post-mortem* examination on the body of a child, a year old, who died of tubercular meningitis and general tuberculosis, an accessory lobe to the left lung was found lying in the pleural cavity between the base of the lung and the diaphragm. It was suspended by a thin pedicle of blood-vessels and connective tissue to the descending aorta, from which it received a small vessel, and its vein entered the hemiazygos. It was covered by pleura, but freely movable, and there was no connection whatever with the lung or any communication with any part of the air passage. It measured about two inches long by one broad, was flattened on the posterior surface, rounded anteriorly, and had the appearance of foetal lung.

Sections under the microscope showed lung tissue, containing bronchioles lined with columnar epithelium, thick-walled, unexpanded air-vesicles, and large masses of caseating tubercle with well-marked giant-cells, also a plentiful supply of blood-vessels.

Such a condition is rare. I have only been able to find record of two similar specimens, one described by Rokitansky,¹ the other by Professor Rektorzik² of Vienna. The latter offers in explanation of this anomaly, that a constant notch is to be seen at the lower part of the posterior border of either lung, by which a small elongated process is marked off from the inferior lobe.

It is not easy, however, to understand how this lobule comes to be so completely isolated from the lung and remain connected with the aorta low down. A suggestion was made by Professor Macalister, to whom the specimen was shown, that a

¹ *Lehrbuch der Pathologischen Anatomie*, 1861.

² *Zeitschrift der k. k. Gesellschaft der Aertze der Wein*, 1861, No. 1.

portion of the viscus may have been constricted off by the arch of the aorta by a process analogous to the separation of the abnormal azygos lobe by the vena azygos on the right side, cases of which have been described by Dr Chiene in *Journal of Anatomy and Physiology*, vol. iv. p. 891, by Dr Collins in the *Transactions of the Royal Irish Academy* (1874), and by Dr Allen, *Journal of Anatomy and Physiology*, vol. xvi.

A CASE OF ABNORMAL DEVELOPMENT OF THE
REPRODUCTIVE ORGANS IN THE FROG. By A.
F. S. KENT, *Magdalen College, Oxford.* (PLATE XVIII.)

ABOUT the end of January in this year (1885), in the course of work at the Oxford Museum, a case occurred of abnormal development of the reproductive organs in a frog, and as the subject seems to be attracting some little attention at the present time, at the suggestion of Mr Robertson I determined to give a short account of it, together with a rough sketch of the principal points in which the specimen under consideration differs from a normal frog.

When the frog was brought up from the tank it was thought to be an ordinary male, as the characteristic glands were present on the thumbs, and equally developed on both sides, and it was not until it had been opened that it was discovered that there was anything peculiar about it. Upon the internal organs being brought into view, however, the first thing to be seen was a well-developed and much convoluted oviduct on the right side, whilst on the left there seemed scarcely any sign of one. Closely applied to the right testis, also, was observed a dark mass which, except in size, was much like an ordinary ovary.

Upon closer examination, it appeared that the Müllerian duct although present on the left side, was quite rudimentary, and in fact little more than a mere thread, slightly convoluted above and straight below. At this stage, the frog, being thought worth some careful dissection, was placed in spirit for several days to harden. The stomach and intestine were then cut away and part of the pelvis removed to bring the cloaca into view. The sternum also was cleared away in order that it might be seen how the Müllerian ducts commenced. Upon a more careful examination being made, it was found that the right testis was only about one-third the size of the left, and was divided by a well-defined transverse constriction about its middle into an anterior and a posterior lobe. Closely applied to its surface was a strongly pigmented body, which presented upon its surface a number of small knob-like projections, and extended

farther over the body of the testis behind than in front. This body evidently represents the ovary; there was no such body applied to the left testis, which was perhaps slightly larger than usual.

The fat bodies also were a little larger than usual, but otherwise presented no special features, and so have been omitted in the figure. When the Müllerian ducts came to be examined, it was found that the one on the left was quite rudimentary, and, as before stated, little more than a mere thread; it was possible, however, to pass a very fine probe some way up it; the duct was slightly convoluted above and straight below; it opens above in a well-defined orifice close to the root of the lung, and at its lower extremity is dilated and ends in a glandular swelling, which is fused with the vesicula seminalis; their internal cavities, however, do not communicate with each other.

The Müllerian duct on the right side was almost as largely developed as in a normal female, and much convoluted; its upper end terminated in a well-defined orifice in the normal position, but its lower end, instead of dilating to form the uterine dilatation, rather became narrower and its walls became slightly thicker, so giving some indication of the gland in which the left oviduct ended; this glandular portion of the duct was fused with the vesicula seminalis, as on the left side, but their internal cavities did not communicate. The vesicula seminalis on the right side is rudimentary but that on the left is normal.

On the right side, as on the left, the Müllerian duct and the Wolffian duct enter the cloaca separately.

From what has been said this specimen would seem to be more male than female, as, in addition to the fact of its having two testes and only one ovary (and that one smaller than usual), the characteristic glands were present upon the thumbs as in a normal male frog. No histological examination of the ovary and testes has yet been made.

The specimen will be set up by Mr Robertson and placed in the court of the University Museum at Oxford.

For the convenience of those interested in the subject it may be well to state that a paper appeared in the *Journal of Anatomy and Physiology* for January 1884, in which Professor Marshall described four cases of abnormal conditions of the reproductive organs in the frog.

These cases, however, differ in many respects from the one now under consideration. *In the first case*, the testes were of normal shape, free from pigment, and slightly larger than usual, the left being slightly larger than the right.

The fat bodies were of great size and more firmly adherent than usual to the testes.

The Müllerian ducts were much convoluted tubes, with firm walls dotted with pigment cells along the greater part of their length.

The lower end of the duct was dilated for a length of about 9 mm., forming a thin-walled sac 3 mm. in width, with strongly pigmented and dilatable walls.

This sac was fused with the lower end of the Wolffian duct. The cavities of the two ducts were, however, quite distinct from one another.

The lower end of the Wolffian duct was slightly dilated, forming a vesicula seminalis similar to that of the normal male frog, but of much smaller size.

In the second case, the testes were rather elongated and slightly irregular in shape, though of normal size. Each was pigmented along its outer border for about the upper two-thirds of its length.

At the anterior end was a small clump of spherical bodies, strongly pigmented, and closely resembling ova in appearance.

The vasa efferentia were normal on both sides.

The Müllerian ducts agreed closely with those of an ordinary adult female.

The Wolffian duct was dilated below the kidney, and was fused for the last 5 mm. of its length with the uterus; as in the first case, however, the cavities of the two ducts were quite distinct from one another, and their openings into the cloaca separate, as in the female frog.

In the third case, the left testis was much larger than usual; somewhat pear-shaped and strongly pigmented upon its surface.

The right testis was almost completely absent.

The vasa efferentia were normal on the left, absent on the right.

The Müllerian ducts on both sides were convoluted tubes, dilated at their lower ends to form thin-walled sacs, which were fused with the Wolffian ducts for a length of 6.5 mm. These latter ducts were of equal size on the two sides in spite of the difference between the two testes, and presented glandular enlargements at their lower ends corresponding to vesiculæ seminales. The cavities of the two ducts did not communicate.

In the fourth case the ovary was present on the left side only, and was divided by a strongly marked transverse constriction into two lobes, whereof the anterior and smaller was subdivided by a less pronounced constriction into two, and the posterior into four minor lobes.

The whole ovary was of a deep brown or black colour, and its surface was distinctly mapped out into polygonal areas.

The testis which replaced the ovary on the right side was 15 mm. long by 8.5 mm. wide and 6 mm. thick. It was marked into two unequal lobes by a deep transverse groove. On the dorsal surface of the testis, at its anterior end, was a deeply-pigmented lobe from which

the pigment was continued down the outer side of the testis as a broad stripe.

The vasa efferentia and the blood-vessels were normal. The fat body was unusually small. The ducts had the normal female arrangement

A case of the occurrence of an ovotestis in *Rana temporaria* is also described by Mr A. G. Bourne at page 83 of the *Quarterly Journal of Microscopical Science* for January 1884.

This specimen presented a well-developed ovary on the right side, whilst on the left was the organ in question. It was completely ovarian in its posterior half, and there was no line of separation between ovarian and testicular portions. The testicular portion was rounded, and tended to assume the shape of a normal testis; it contained motile spermatozoa.

Some sections of the gland were cut, which showed that neighbouring follicles had developed some ova, others spermatozoa, both in a normal manner.

Professor Moseley has directed my attention to a paper by Mr J. Bland Sutton, to be found at page 129 of the *Journal of Anatomy and Physiology*, vol. xix. pt. ii.

EXPLANATION OF PLATE XVIII.

Fig. 1. *h*, heart; *i*, cut end of intestine; *k*, kidney; *l*, lung; *m*, Müllerian duct; *t*, testis; *v*, vasa efferentia; *v.s.*, vesicula seminalis; *w*, Wolffian duct.

In fig. 2 the left testis has been turned on one side to show the vasa efferentia and the whole course of the left Müllerian duct.

ROTATION AND CIRCUMDUCTION. By THOMAS DWIGHT,
M.D., *Parkman Professor of Anatomy at Harvard University.*

As Professor Heiberg¹ admits that the ulna does not rotate, and as I have not questioned the accuracy of his experiments, but only what I conceived to be his interpretation of them, there is no point of great importance at issue between us. I am unwilling, however, to allow some of Professor Heiberg's statements to pass unanswered. I shall take no other notice of the personal tone of Professor Heiberg's reply, than to assure him that if I at all overstepped the limits of courtesy in my criticism I sincerely regret it. Having declared that the ulna rotates he explains, that, had he written in English, he should have said it is circumducted, but that he never had heard the word circumduction in seven years passed in anatomical and surgical circles on the Continent, and, indeed, did not know it when he published his book. He writes:—"When I have been misunderstood by Professor Dwight, and perhaps by many others, I suppose the cause lies therein, that the verb rotate has a much more restricted signification in English than it has in the German, Scandinavian, French, Italian, and other Roman languages that I may know."

I cannot but think that Professor Heiberg is mistaken in believing that he never heard the word circumduction on the Continent, for I find it on page 36 of his own book, near the beginning of a quotation from Cruveilhier. Had he quoted Duchenne continuously instead of omitting section 137 he would have seen it twice more. The difference between rotation and circumduction is perfectly familiar to students of English anatomical literature. In French the terms are used in precisely the same way. Cruveilhier, in his enumeration of movements, mentions—"3° le mouvement de *circumduction* ou *mouvement en fronde* dans lequel l'os mobile décrit un cône dont le sommet répond à l'articulation, et la base à l'extrémité opposée

¹ "Movements of the Ulna in Rotation of the Fore-Arm," this *Journal*, vol. xix. p. 237.

de l'os: 4° le *mouvement de rotation*, dans lequel l'os soule sur son axe, sans se porter d'un lieu à un autre."

Sappey describes circumduction in essentially the same way adding, "En décrivant ce cône il (l'os) se trouve successivement en adduction, flexion, abduction, extension, et dans toutes les situations intermédiaires." "Le *mouvement de rotation* diffère beaucoup du précédent. L'os qui en est le siège ne tourne pas autour d'un axe idéal pour décrire un cône à base plus ou moins large. Il reste en place et tourne autour de son axe, ou autour d'une ligne parallèle à cet axe." It is not necessary to multiply quotations, for it would be difficult to find a French treatise on anatomy of the present time in which the distinction is not made.

It is true that the word circumduction is not used in German, but the word rotation is used as in English and French. Henle,¹ in describing the ball and socket-joint, states that the head of the bone can be moved in any direction and in every position can be turned on an imaginary axis perpendicular to the socket. "Die Drehung der letzteren Art wird insbesondere mit dem Namen Rotation bezeichnet." He teaches, concerning the saddle-joint, that the bone moves on two axes, crossing one another at right angles, *but does not rotate*, and gives as an example the carpo-metacarpal joint of the thumb. It is fair to say that in denying rotation in the egg-shaped joint he adds in a parenthesis ("im engeren Sinne des Wortes"). Henle's remarks on the hip-joint show very clearly that he uses the word in the strict sense. He states that the Webers found the rotation to amount to 51° and Henke to rather more. He cannot have meant circumduction, for that is continuous in the hip.

Professor Hermann v. Meyer² gives the following scheme, which is very simple:—Imagine a globular head of a bone on which a much smaller one, with a correspondingly concave base, may move freely. Suppose the latter to move from the centre of the head to its edge, and then, moving round the periphery from flexion in one direction to flexion in another, to describe a part of a cone, it executes "*peripherische Bewegungen*," which is the same as circumduction. If the bone in whatever position it may

¹ *Bänderlehre*, p. 14, 1872.

² *Lehrbuch der Anatomie des Menschen*. Dritte Auflage, 1873, p. 49.

take can turn on its own axis, "wir nennen diese Bewegungen *Drehbewegungen oder Rotationen*."

It seems, therefore, that Professor Heiberg's use of the word rotate was far from accurate. He claims, however, that because he explained that the surface of the ulna describes part of the surface of two cones, one above and one below the joint, it was evident that he did not mean rotation, but circumduction, and that certain curves which he figures could never be obtained by simple rotation. I certainly shall not dispute the last proposition, as far as it applies to the curves made by the ulna, but I deny that, because a bone describes a part of a cone, it necessarily implies circumduction, and also that the curve made by a pencil continuing the outer border of the radius when the ulna is fixed is the result of anything but pure rotation. Such a curve is one of those that Professor Heiberg refers to, and he reproduces it in his paper in the *Journal* as fig. 2. The movement of the radius, in this case, is one of simple rotation on the classical axis passing through the head of the radius and that of the ulna. That the bone describes part of a cone, and that the rod prolonging it describes a curve, are entirely accidental circumstances, depending on the shape of the bone, and not on the nature of the movement. A rod inserted transversely into the radius gives unequivocal evidence of rotation. For these reasons the fact that Professor Heiberg asserted that the ulna describes parts of two cones is not itself evidence that it does not do so by rotation.

Another reason for supposing that Professor Heiberg used the word in its proper sense is that he appears to agree in the main with Lecompte, though saying that he goes too far. Now Lecompte writes that "le cubitus exécute sur la trochlée humérale un mouvement de torsion spiroïde." Is it not evident that this is a modified rotation?

I am bound to admit, however, that had I studied more carefully the figures representing Professor Heiberg's model near the end of his book, I might have known, in spite of his use of terms, that he did not mean that the ulna rotates.

The question arises, apart from any controversy, whether the terms rotation and circumduction are sufficiently well defined in English and French. There is no confusion as to the idea, but

the definition of rotation is too restricted, and the term circumduction is sometimes improperly used. Rotation is generally described as the movement of a bone on its own axis, or, as by Sappey, also on a line parallel to it. A moment's reflection shows that this definition is correct neither for the femur nor the radius. As to the second point, we find in Quain, Cruveilhier, and Sappey that the head of the radius rotates, and that the lower end is circumducted round the ulna, but we find no explanation how the two ends of a bone can execute essentially different movements at the same time.

The error arises from losing sight of the real nature of the movement, which depends on what axis or combination of axes it occurs. If we define rotation as movement on one axis approximately parallel to the long axis of the bone, and circumduction as movement on two transverse axes by which a bone passes from flexion in one direction to flexion in another, describing more or less of the surface of a cone, we have definitions based on a scientific principle, and which prevent confusion between these movements. It is clear from the quotations given above that this is not offered as anything new.

ON THE MOVEMENTS OF THE ULNA IN PRONATION
AND SUPINATION. By C. W. CATHCART, M.B., F.R.C.S.,
Lecturer on Surgery, Edinburgh.

SINCE I read a paper under the above title at the Worcester meeting of the British Medical Association in 1882, the subject has in some ways been very fully treated by Professor Heiberg,¹ and discussed for three days (as he mentions in the April number of this *Journal*) at the Anatomical Section of the International Congress, held last year in Copenhagen.

The delay in publishing my paper has therefore rendered it unnecessary for me now to enter at length into many details which I then discussed, while it has relieved me of the task of collecting references to the literature of the subject, since this has meanwhile been more thoroughly carried out by Professor Heiberg than I could well have hoped to do.

Through Professor Heiberg's advocacy, it seems likely to be no longer a question of doubt now that the ulna participates in pronation and supination of the fore-arm, and that it does so by a movement of circumduction, sweeping round in the reverse direction to that taken by the lower end of the radius. I hold, however, that it is still open to discussion as to what joint or joints are involved in this movement of the ulna, and, further, as to the forces which produce it in the living arm.

In a former paper² I ventured to assert what I would again revert to, that in all questions such as the present our first and last appeal should be to the living and moving person. According to this principle, therefore, the problems before us would fall for consideration in the following order:—(1) Does the ulna move in pronation and supination? (2) If so, in what way does it move? (3) Where does the movement take place? (4) What moves it? The reason, as it seems to me, why so many anatomists have missed the truth in this question is that they

¹ "Ueber die Drehung des Vorder arms," *Christiania Videnskabselskabs Forhandlinger*, 1883, No. 8.

² "Movements of Shoulder-Girdle involved in those of the Arm on the Trunk," *Jour. of Anat. and Phys.*, vol. xvii. pt. 2.

have taken the third problem first. At the outset, they have argued that because they could see no provision for a lateral movement of the ulna at the elbow-joint, that no such movement could take place, and, therefore, that all appearances of such movement must in reality be due to some delusion. Now, however, we may assume that careful observation of the ulna on the living arm, Lecompte's ring experiment, and Professor Heiberg's able discussion of the subject, and his graphic method of demonstration, have answered the first two questions, and made it sufficiently clear that in pronation and supination the ulna passes, by a movement of circumduction, through a segment of a circle or at least some approximately circular arc. Let us therefore discuss the next question—the third. Where does the movement take place?

If we analyse any movement of circumduction which lies in say a vertical plane, we can reduce it to a combination of movements in two planes, at right angles to one another, and perpendicular to the first. It is not, however, necessary that these movements should take place at the same joint. By the varying combination of the two movements an endless variety of curves may be produced, as is seen in the curves traced by the sympalmograph.

For illustration, let us suppose the upper arm hanging by the side, with the fore-arm flexed to a right angle, and projecting forwards. The circumduction of the ulna in pronation and supination would then be due to a combination of movements in two planes, one of which we may call the vertical, occurring by flexion and extension at the elbow-joint, and the other the horizontal, the exact seat of which we have now to determine. Possibly this horizontal movement might be incapable of being separated from its vertical combination, *i.e.*, an oblique movement might be alone possible at the elbow; possibly a horizontal or lateral movement might be possible at the elbow; or, possibly, the movement might not be at the elbow at all, but at the shoulder-joint. In this case, either a lateral rotation of the humerus, the ulna being set at an angle to it, or an adduction or abduction of the humerus, combined with flexion or extension and rotation, would produce the necessary lateral alteration in the position of the ulna.

The view, which I formerly maintained and still hold to, is, that while this lateral movement of the ulna in circumduction may, and probably does, take place to a limited extent by an oblique movement at the elbow, it chiefly occurs at the shoulder-joint. It is to the latter of these movements that I wish to direct attention in this paper. No one, of course, denies that in forcible pronation and supination the upper arm moves to and from the side. It is in gentle movements of rotation, however, when the upper arm can be maintained, to all appearance, perfectly steady, that there is difficulty in deciding, and it is in such movements that I hope to prove that a rotation of the humerus is the chief agent for the lateral movement of the ulna. By referring to Professor Heiberg's¹ collection of the literature of the subject, I find that this view is held by Dr R. W. Einthoven.² Dr. Einthoven believes that by firmly pressing over the condyles with the fingers while the fore-arm is rotating within one of Lecompte's rings, the slight rotatory movements of the humerus can be recognised, and their similarity noted to purely rotatory movements without accompanying pronation or supination. Professor Heiberg criticises this view in an appendix to his paper, and brings two objections against it:—

1. That he has failed to get the same results in repeating Dr Einthoven's experiments.
2. That by experimenting on a dead arm he has found that as much movement as is necessary is possible at the elbow, without calling into play the shoulder-joint at all.

In regard to the first objection I can only say that, working independently of Dr Einthoven, I had come to much the same results from similar experiments; with only this exception, that I could not say that the ordinary movement of rotation of the humerus was exactly like that in pronation and supination. This, however, I accounted for by the complication of surrounding muscular contractions in the latter case which was not present in the former. As to the second objection, it might be transposed so as to tell as much *against* the elbow movement as

¹ "Zur Geschichte der Lehre von der Drehung der Hand," *Christiania Videnskabselskabs Forhandlinger*, 1883, No. 11.

² Quelques remarques sur le mécanisme de l'articulation du Coude, *Archives Néerlandaises*, tome xvii. p. 289.

for it; by arranging a dead arm properly, the necessary lateral movement of the ulna might be made to take place at the shoulder-joint without calling into play the elbow. I would rather, however, not appeal to the dead arm at all until we have exhausted every possible means of inquiry on the living. Undoubtedly the inquiry is a difficult one. The amount of movement of the condyles of the humerus is at most very small (about $\frac{1}{8}$ inch, or 5 mm.); the skin is so movable that such slight movements of the bones are difficult to observe accurately; and the contraction of muscles in the neighbourhood is decidedly confusing to one's sense of touch. Is there no other way, one naturally asks, to bring the matter to a more searching test? One way would be to screw long needles or pointers into one or both condyles of a living arm; but this seems to be attended with rather too much risk to be lightly undertaken. On thinking the matter over, however, it occurred to me that there was still another method available, *i.e.*, to study the movements of pronation and supination in patients where, by an ankylosis of the shoulder, the movements of that joint are eliminated. If the shoulder is not involved in pronation and supination, its ankylosis should make no difference to these movements. If the shoulder, however, is normally involved, then its ankylosis should bring about some deviation from the normal mode of performing pronation and supination which ought to be traceable to this cause. Such cases of ankylosis of the shoulder, although not uncommon, are not always easy to find when one wants them. I have had an opportunity of examining three, although it is only to the last of them—at present within reach in Edinburgh—that I have been able to apply all the tests I wished. They all corroborate the view that the shoulder-joint is concerned in pronation and supination.

The first case was seen in August 1882. The patient was a woman of about 60, under the care of Dr Forster of Daventry. There was disease of the right shoulder-joint of fourteen or fifteen years' standing, with several sinuses, some of them still open. Ankylosis was nearly complete, and pain accompanied the slight amount of movement that still remained. Pronation and supination were performed by the affected arm in a jerky and hesitating way, and incompletely. When urged to perform

the movements more thoroughly she made an effort, pronated strongly, and immediately put her left hand up to her right shoulder, complaining of the pain there. When the humerus was steadied by being firmly held against the side, pronation and supination were performed more easily, but incompletely also, and the ulna could be seen to be nearly motionless while the radius moved round it.

It is worthy of notice that it was a movement of strong pronation which elicited the pain; had it been supination, the long tendon of the biceps might have been blamed for it. It does not seem unreasonable to account for the pain by the slight movement produced in the sensitive shoulder-joint by the co-ordination of outward rotators of the humerus with pronators of the radius; and, for the usual uncertainty of the movements, by the fear of producing that complete form of pronation and supination which involves rotation at the shoulder. The details of the case are from notes taken at the time.

The next case was that of a young man whom I saw in Mr Miller's ward as an out-patient, in September 1884. He had lately recovered from an attack of rheumatic fever, which had left an apparently complete ankylosis of the right shoulder, and atrophy of the deltoid. All his other joints and muscles seemed in good condition. On stripping him to the waist and getting him to hold an instrument between the index and middle fingers of his closed right hand, I found that he easily performed the movements of pronation and supination, but moved his humerus to and from his side as he did so. This was visible both in the humerus and in the scapula which moved with it. When the humerus was held as steadily as possible, the rotatory movements of the fore-arm were much impaired. Similar movements with the left arm showed no such visible tendency to move the humerus, nor did steadying of the bone in any way seem to affect the movements. These experiments were repeated several times, and those present (a house surgeon and several students) were quite satisfied as to the results. I had not my metal ring with me, and did not have any opportunity of examining the patient again. The notes of this case are quoted from memory.

The explanation of the inward movement of the whole humerus appears to be that, as a rotation of the humerus on its own axis

was necessarily difficult or impossible, the next best way to gain the same end was to move the ulna laterally together with the humerus. When this was hindered, so was the movement of pronation and supination. He had not yet learned to bend his hand over his fore-arm, and thus make up, in part, for the lateral movements when they were interfered with.

The third and last case is that of a young man, aged 23, who is still under observation. At eight or nine years of age he suffered from what appears to have been disease of his right shoulder-joint, for which the actual cautery was freely applied by the late Professor Spence. The disease subsided, but left behind it a firm ankylosis of the joint, which has persisted ever since. As is usual in such cases, the compensatory mobility of the scapula is so great that it would be difficult to believe that his right shoulder had not its full use, were it not that a careful examination manifests the contrary. As a proof of the usefulness of his right arm, I may mention that he served in the militia during part of six consecutive years without the condition of his right arm having been discovered.

When stripped, his chest and back muscles are seen to be well developed, the pectoralis major being rather stronger on the left side, and the upper part of the trapezius on the right. The right deltoid is much atrophied. A large scar resulting from the cautery is seen in front and behind his right shoulder-joint. The right arm, from the acromion process to the tip of the middle finger, measures 4 inches less than the left; of this $3\frac{1}{2}$ inches is due to shortness of the humerus, and $\frac{1}{2}$ inch to that of fore-arm and hand. The muscular development of the right arm is good, the deltoid being excepted; upper arm, $8\frac{3}{4}$ inches; fore-arm, 9 inches. On the left side these measurements are $\frac{3}{4}$ inch greater in each case. The remaining joints of the right arm are perfectly free, and their movements, to all appearance, quite natural.

1. When the right fore-arm is flexed to about a right angle, and a circular metal ring¹ adapted closely round the wrist and held steady, the patient can rotate his fore-arm within the ring.

¹ For some time I have used a convenient form of ring made for me by Mr Fraser, optician, when I was on the look-out for an easily adaptable metal ring. It consists of a piece of strong clock-spring, $9\frac{1}{2}$ inches long and $\frac{1}{2}$ inch wide. Into one end is soldered smoothly a small male screw directed outwards from the concavity. Beginning an inch from the other end is cut a longitudinal slit 2

With each movement of supination, however, the humerus is brought towards the side to about the same extent as the ulna passes from without inwards in the horizontal part of its circumduction. In pronation these movements are reversed. This is a confirmation of the experiment performed upon Case 2, but is more accurate, in virtue of the application of the ring.

2. If we still keep on the ring, and now ask him to cross his upper arm forcibly over his chest, so that the movements of his scapula, and consequently of his humerus, are restricted, we find that he can no longer rotate his fore-arm within the ring. He can still perform pronation and supination, but the ring must be allowed to move with his radius—in other words, his radius is alone moving; the opposite movement of the ulna, which was necessary to diminish the curve travelled over by the radius, and so permit rotation within the ring, having been restrained simultaneously with the restraint of the humerus. Had the lateral movement of the ulna been chiefly in the elbow, or had it not come from the humerus, why should the restriction of the movements of the humerus have made so much difference in the mode of performing pronation and supination? Where the shoulder has its normal movements this position of the arm has no effect on pronation and supination. As soon as the crossing of his arm was sufficiently relaxed to allow the scapula to move again, the rotation of the fore-arm could again easily be performed within the ring.

Without the ring test this case would have been difficult to study, because the patient, from long practice, had acquired the device of bringing the hand well over towards the ulnar side as soon as his humerus was restricted, and thus he diminished the impairment of rotation round the radial side of his hand, which was easily recognised in the second and more recent case. This confirms the view that there are two ways of modifying the axis of rotation of the hand—(1) by changing the relative position of the hand and fore-arm, (2) by increasing or diminishing the share

inches long, and wide enough to admit the projecting screw. All that requires to be done is to encircle the wrist with the spring, place the screw within the slit, so that the two ends of the spring now overlap, and, having adjusted the ring to the right size, fix the whole by screwing down a nut on to the projecting male screw. The ring becomes practically circular, and has sufficient rigidity for all purposes.

of the ulna in the movements of rotation, and thus throwing the axis of movement nearer to or further from the radius.

It seems to me that these three cases of ankylosis of the shoulder-joint—which by a coincidence were all on the right side—are a means of investigating this question at least equally satisfactory with any artificial experiments on a living arm, and more physiologically reliable than any possible experiments upon a dead arm whether dissected or not.

The forces which produce the lateral movement of the ulna must be left for future consideration. Meanwhile, it will be sufficient if this paper contributes to establishing the important and interesting position that, in pronation and supination of the hand and fore-arm, the lateral movement of the ulna takes place chiefly at the shoulder-joint.

THE ANATOMY OF A HYDROMICROCEPHALOUS
BRAIN. BY ALEX. HILL, M.D., *Fellow of Downing College,
and Demonstrator of Anatomy in the University of Cam-
bridge, one of the Hunterian Professors at the Royal College
of Surgeons of England.* (PLATES XIX., XX.)

THE body of the idiot, from which this brain was taken, was not received in Cambridge until six days after death. Nothing in the external configuration of the head suggested the very remarkable deformity of the brain which really existed, but, as the specimen was evidently one of interest, the skull case was at once injected with spirit. A week was then allowed to elapse before the brain was taken out, when it was found to be in a condition which necessitated very careful handling; it was, however (as shown by Plate XIX., A and B, drawn from photographs), sufficiently hard for general examination. Indeed, a certain amount of *post-mortem* alteration makes it easier to distinguish grey from white matter, and the delay in this case was therefore not unfavourable to the investigation.

Its total weight, after soaking in spirit, was $10\frac{1}{4}$ oz. (291.4 grammes). From this I infer that its weight, when fresh, could not have been more than 15 oz. (425 grammes).

Bischoff found, when investigating the brain of Helen Becker, that a fresh brain might lose by soaking in spirit as much as 40 to 50 per cent. of its weight, but the brain under description being, to a certain extent, decomposed, shrank much less than a fresh one would have done. Its greatest length (after soaking in spirit) was 6 inches, its greatest breadth $4\frac{1}{2}$ inches.

EXTERNAL CONFIGURATION.

All the parts below the cerebral hemisphere were (as shown in Plate XIX., A) small, but otherwise normally developed.

The cerebral hemispheres presented a remarkable deficiency, the ventricles being greatly dilated and their walls formed for the most part of membrane. Not more than one-fifth of the cortex

was developed. This was confined to the frontal region as far back as the front of the anterior transverse convolution, the Island of Reil, which was uncovered, the front part of the temporo-sphenoidal lobes, and the orbital region behind the tri-radiate fissure. Even in these regions the convolutions retained an embryonic arrangement. In the orbital region in front of the tri-radiate fissure, and in the parietal and occipital regions, the cortex was replaced by a smooth convex membrane, varying in thickness from .75 mm. on the upper part to 2.5 mm. on the floor of the occipital region.

These changes being evidently, as shown by the history of the case, congenital, I determined to find out what alterations in the lower parts of the brain were associated with this great cortical deficiency, and to obtain, if possible, accurate measurements of all departures from the normal size. Such an examination can only be satisfactorily carried out by cutting the whole brain into sections. These should be in the first instance just thick enough to allow of their being lifted into separate basins, when, after naked-eye observation, each section can be divided into square pieces of a size convenient for cutting with a microtome if a minute examination appears desirable.

METHOD.

Owing to the softness of the brain I decided to embed rather than freeze it. Much time was spent in finding a suitable material. All the ordinary masses were found too hard for cutting on a large scale, or, if made soft by the addition of oil or lard, the sheet when cut would not hold together. Finally, I discovered that a mixture of one part vaseline to four parts paraffin, melting at 40° C. (supplied by Messrs Brady & Martin) offered extremely little resistance to the knife and yet would cut into sheets which, although 5 inches square, might easily be lifted in the fingers. At the time (July 1883) the weather happened to be extremely hot, in colder weather a larger admixture of vaseline would be necessary. The section-cutter comprised a horizontal wooden platform carried up and down a heavy iron frame by means of a large screw with a $\frac{1}{4}$ -inch thread. To the iron frame was fixed a square iron collar in

which the block of paraffin rested. For knife I used a large backed saw, the toothed edge of which was ground down into a plane cutting edge. It is unnecessary to go into further details with regard to the apparatus, for it was far from being a success. Very great care was necessary in using it to prevent displacement of the paraffin block. Indeed, I doubt whether it is possible, except by some complicated arrangement such as I eventually adopted, to hold the block firmly enough to cut so large a sheet, for very considerable force is used in driving the knife forward, and, owing to the viscosity of the paraffin, any constant pressure produces in time a change of form. However firmly it appears to be fixed, after a few sections its supports are found to be quite loose again. I succeeded in securing the block of paraffin by the contrivance diagrammatically exhibited in Plate XIX. D, and obtained regular uniform sections of $\frac{1}{16}$ inch thick, but the arrangement required a most troublesome amount of attention to the screws.

Plates of wood (Plate XIX., D, *a* and *a'*), on the inner surface of which a large number of transverse grooves were cut, were placed on either side of the embedding mass. By means of four finger screws passing through the iron collar, these plates of wood were screwed firmly at their upper ends against the paraffin. At their lower borders they were united together by strong elastic bands, and thus a constant pressure was brought to bear upon the paraffin, which was so firmly fixed to the iron collar that displacement by the knife was absolutely impossible. When it was required to raise the block, the pressure of the elastic band at the lower end was first taken off the plates of wood by means of the screw *c*, which pressed upon a projecting platform *d* of the plate *a*. When the wood was about $\frac{1}{8}$ of an inch from the paraffin at its lower end on either side, the four finger screws passing through the iron collar were loosened. The tension of the elastic bands keeps the sheets of wood in contact with these screws which they consequently follow towards the collar on either side and away from the paraffin. So gradually and uniformly are they withdrawn that the paraffin is left free upon the stage without any perceptible displacement. The stage was raised $\frac{1}{8}$ of an inch (1.5 m.m.), the finger screws through the collar again tightened,

the screw *c* withdrawn from the platform *d* and the paraffin block firmly clamped in its place, and held there by the pressure of the elastic bands.¹

Each section as it was cut was removed to a basin of spirit and set aside for subsequent examination.

Fig. 1 is from a drawing of the upper surface of the brain before it was cut up. In the photographs the raggedness of the surface and the indistinctness of its contours are unduly conspicuous. The sketch, although slightly restored, gives in reality a very much better idea of the appearances actually presented. The cross lines indicate the plane of every second section from section 20 to section 70.

The great diminution in the amount of cortex appeared to offer an opportunity of solving some of the most important questions with regard to the relation to one another of the different parts of the brain. The apparently uniform diminution in the size of the mid brain, hind brain, and cord, held out very little hope of my being able to determine proportional inequalities in the development of the different structures of which these parts are composed. Evidently the parts of greatest interest were the internal capsule, the nuclei caudatus and lenticularis, and optic thalamus, and of the sizes of these it was desirable to obtain accurate measurements. No better method of doing this occurred to me than to measure off upon a series of lines ruled $\frac{1}{8}$ of an inch apart (the thickness of a section) the surface diameter, in a certain plane, of each successive section, and then upon another series of lines the diameters taken in a plane at right angles to the first. In this way, two ideal longitudinal sections in planes at right angles to one another were constructed; no notice, however, was taken of the curvatures of the principal axis of the structure under examination. As mentioned above, a well-developed brain hardened in spirit was cut up with the same machine. The photographs in Luys' "*Iconographie*" were also used in the comparison. Ideal sections of the control brain were also constructed in the manner just stated, and since the questions at issue would not be affected by minute inaccuracies of measurement the

¹ I am much indebted to the Cambridge Scientific Instrument Company for the trouble they took in perfecting this apparatus.

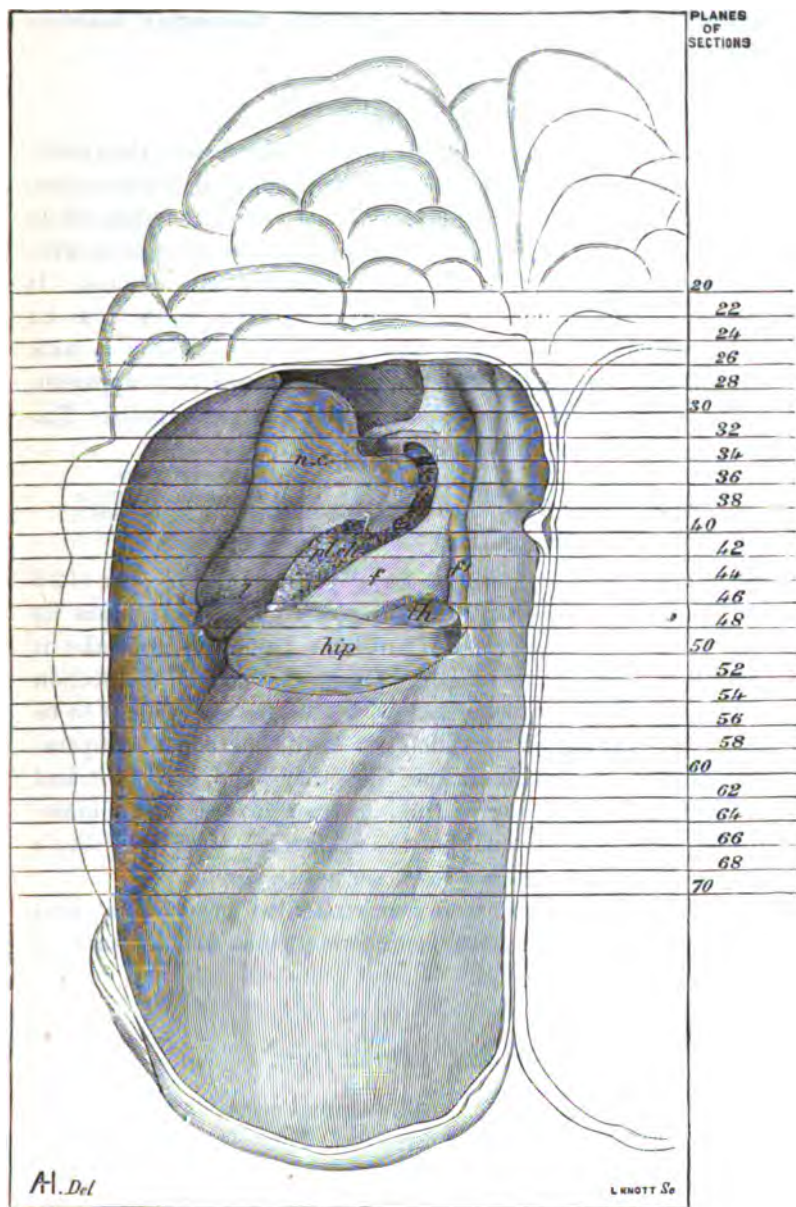


FIG 1.—Dorsal surface of brain after removal of upper part of membranous wall. The floor of the lateral ventricle behind line 52 was also membranous. NC, nucleus caudatus; NL, nucleus lenticularis; *pl. ch.*, choroid plexus; *f*, fornix; *f'*, fornix of opposite side; *th.*, thalamus opticus; *hip*, hippocampus major.

method was for all practical purposes thoroughly satisfactory.

NUCLEUS CAUDATUS.

This, as seen in Plate XIX., B, projected freely into the ventricular cavity. It will be noticed that its head, as shown in section 28, projected forward beyond the level of the surrounding white matter. On its under surface the nucleus was in contact with the internal capsule, from which it no doubt received fibres. It was only possible, however, for it to give off fibres from its under and outer part. The grey processes connecting it with the nucleus lenticularis on its outer side were very apparent, owing to the small development of the internal capsule. The head of the nucleus measured—

		<i>Control Brain.</i>	
Greatest width, $\frac{1}{2}$ in. (13 mm.),	} as against	Width, $\frac{1}{2}$ in. (13 mm.).	}
Depth, 1 in. (25 mm.),		Depth, $\frac{1}{2}$ in. (21 mm.).	
Length, $\frac{1}{2}$ in. (13 mm.),		Length, $\frac{1}{4}$ in. (9 mm.).	

The greatest width shown in Luys' photographs is $\frac{1}{2}$ in. (12.5 mm.); greatest depth, $1\frac{5}{8}$ in. (33 mm.). The photographs do not follow one another with sufficient regularity to make it possible to estimate the length. The greater size of the section in the photograph, as compared with the control brain, is to be fully accounted for by the difference in the method of preparation. In the control brain, on the other hand, the spirit had probably caused greater shrinking than in the idiot's brain. Nevertheless, it is obvious that the *nucleus caudatus in the idiot's brain was not by any means below normal in size.*

Tongues of grey matter were seen stretching across the internal capsule towards the nucleus lenticularis, which first appears on the left side in section 29.

NUCLEUS LENTICULARIS.

Nucleus lenticularis occupies its normal situation with regard to the internal and external capsule. The claustrum also is normally developed.

Size.—There is one section of the nucleus lenticularis which is always easy to identify—that, namely, in which the anterior commissure first touches or enters the yellow nucleus. This

occurs in my section 39; and it is peculiarly noteworthy that when this is compared with the same section in Luys' *Iconographie*, it is found to be of *precisely the same size*, notwithstanding the fact that there are reasons for believing, as stated above, that the brain from which it was taken had shrunk to a greater extent than had the one from which Luys made his photograph.

Measurements as projected on ruled paper:—

Idiot's Brain.	Control.	Luys.
Width, $1\frac{1}{2}$ in. (24 mm.). Depth, 1 in. (25 mm.). Length, $\frac{3}{4}$ in. (22·5 mm.).	Width, $1\frac{1}{2}$ in. (24 mm.). Depth, $\frac{3}{4}$ in. (19 mm.). Length, $1\frac{1}{2}$ in. (32 mm.).	Width, $\frac{1}{2}$ in. (22·5 mm.). Depth, 1 in. (25 mm.).

The transverse section of the nucleus was therefore above normal, its length below normal; but certainly *its total size was not less than it would have been in a well-developed brain*. It is scarcely necessary to remark that its weight proportionately to that of the whole brain must, under these circumstances, have been nearly three times as great as normal. The proportional weight, however, does not appear to me to be the matter of interest. The question is rather, What changes in weight are associated with those deficiencies upon which the small weight of the whole brain immediately depends?

NUCLEUS AMYGDALEUS

Nucleus amygdaleus was singularly conspicuous, owing to the comparative want of convolution of the cortex of the temporo-sphenoidal lobe. It was not below normal in size.

Width, $\frac{7}{16}$ in. (11 mm.). Depth, $\frac{1}{8}$ in. (14 mm.). Length, $\frac{1}{8}$ in. (8 mm.).

OPTIC THALAMUS.

The determination of the size of this nucleus is a matter of much greater difficulty. Certain sections, however, are easy to recognise and compare. For instance, the one in which the Bundle of Vicq d'Azyr is seen leaving its lower border. This

occurs in section 46, the measurements of which are as follows:—

		Control.	Luys, pl. xxx.
Greatest oblique diameter	$\frac{1}{2}\frac{1}{2}$ in. (20 mm.)	$\frac{1}{2}$ in. (19 mm.)	$\frac{1}{2}\frac{1}{8}$ in. (23 mm.)
At right angles to above .	$\frac{1}{8}$ in. (14 mm.)	$\frac{1}{8}$ in. (17 mm.)	$\frac{1}{2}$ in. (19 mm.)

The total length of the thalamus I was unable to obtain. It was evidently, however, short, and the deficiency of development appeared to affect its posterior part; for beyond section 46 (the one just mentioned) the optic thalamus begins rapidly to dwindle, while normally it should go on increasing. No thalamus is to be seen after the clear appearance of the superior peduncles of the cerebellum, the substantia nigra, and posterior white commissure; nor does it reach more than $\frac{1}{8}$ inch farther back than the nucleus lenticularis. The pulvinar portion was therefore abnormally small. The nucleus of the habenula was well developed as was also Luys' nucleus of the tegment.

CORPUS CALLOSUM totally absent.

ANTERIOR COMMISSURE in all respects normal.

POSTERIOR COMMISSURE normal.

FORNIX small, but in other respects normal.

INTERNAL CAPSULE was, as one would expect, extremely reduced in size. In its anterior part it was freely bridged across by the grey connections of the two nuclei of the corpus striatum. In its middle part in some regions it could hardly be said to exist. For instance, in section 44, the yellow nucleus almost touches the optic thalamus. In this same section, however, a not inconsiderable amount of white matter is to be seen lying above the yellow nucleus.

Many other points in the anatomy of this brain remain to be worked out, and I have set aside its various sections with the intention of cutting some of them into square blocks, and then into sections for the microscope. But undoubtedly the first importance attaches to the size of the two nuclei of the corpus striatum. These, as stated above, have not only *not* suffered any diminution in volume proportional to the diminution of the cortex, but are even as large as in a well-developed brain. This

appears to me to prove absolutely that the common view with regard to their connections and functions is erroneous. They cannot be connected, on the one hand, with the cortex, and, on the other hand, with what I have termed the basal or central grey tube (the grey matter of the cord and base of the brain); nor can they be functionally middle-men between these two grey masses. In other words, the introduction into Meynert's scheme, which is an attempt at an anatomical expression of the current physiological doctrines, of a central node, is contrary to evidence. Wernicke (*Lehrbuch der Gehirnkrankheiten*) has introduced an entirely new conception of the anatomical relations of the corpus striatum. On the ground of the continuity of the head of the nucleus caudatus with the grey matter of the anterior perforated space, and of its tail with the cortex of the temporo-sphenoidal lobe" (fig. 2), he regards it as an involuted portion of the cerebral cortex. The nucleus lenticularis is inseparable from the nucleus caudatus, and must be placed in the same anatomical category. Several

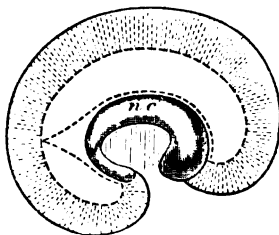


FIG. 2. After Wernicke.

additional arguments might, I think, be adduced in favour of Wernicke's view. For instance (1) as remarked by Cuvier, the bird's cerebrum consists almost entirely of corpus striatum. This does not of necessity disprove the current view that this organ is a centre of reflex action inferior in value to the cortex, but unless the corpus striatum be of the same morphological and functional value as the cortex, birds must differ from mammals in being almost devoid of that highest part of the central nervous system, in which (in mammals) we have reason to believe consciousness and volition reside. (2) The nucleus amygdaleus, a not inconsiderable structure, and deserving of a good deal more attention at the hands of anatomists than it has hitherto received, is undoubtedly, from its connections and development a portion of the cortex. In minute structure it resembles the corpus striatum. (3) The optic thalamus, as I have attempted to prove elsewhere,¹ develops in the same way, and has the

¹ *The Plan of the Central Nervous System*: a thesis for the degree of M.D. in the University of Cambridge. Deighton & Bell, Cambridge, 1885.

same connections as the rest of the grey matter surrounding the neural canal. This grey matter throughout the whole of the cord and the hind and mid-brain is entirely used up in forming the primary centres of the motor, visceral, and sensory nerves. There is no reason to suppose that the optic thalamus makes a departure from this rule. It appears to me to consist of the primary centres of the optic and olfactory nerves. Like the other primary centres it is developed from a layer of cells lying immediately on the outside of the epithelium of the neural canal, and gives rise by its cell-processes to the white fibres with which it is surrounded, and from which presumably the optic and olfactory nerves are derived. Its peculiar isolation depends upon the fact that no motor nerve arises from the fore-brain. In minute structure it resembles the sensory grey matter of the cord. A marked feature in the development of this grey matter is its being built up around a small cell formation, which afterwards becomes the substantia gelatinosa of Rolando. Löwe (*Entwicklungsgeschichte des Nervensystems*, vol. i. p. 102) has shown that this tissue is to be found in the "centre médian" of Luys of the optic thalamus. The corpus striatum belongs to quite a different part of the central nervous system, being developed, not in the primary wall of the neural canal, but in the wall of a vesicular outgrowth from its anterior part (the cerebral hemisphere). There is no reason to believe that the grey matter of the central tube is continued into these vesicles any more than that nerves primarily arise from these vesicles, and consequently need their primary centres within them. In other words, the optic thalamus belongs to an order of structures unrepresented in the cerebral hemispheres; to what is essentially the basal part of the central nervous system, the part in immediate connection with the peripheral nerves. The old group of "basal ganglia" being thus broken down, the corpora striata are either a part of the cortex or masses of grey matter not elsewhere represented in the system. The former hypothesis is in all respects the most probable.

We may look upon the basal part of the central nervous system, or, as I prefer to call it, having regard to its development, the "central grey tube," as consisting of cells, the fibres of which constitute the peripheral nerves. The various con-

siderations urged above show that there is no reason for separating the optic thalami from the rest of the central grey tube. On the other hand, there is no reason, either phylogenetic or ontogenetic, for considering the corpora striata as a part of the central grey tube; on the contrary, there are many reasons for looking upon them as belonging to the same system as the cerebral cortex. If they are not of the same morphological value as the cortex, as Wernicke, with good reason, I believe, considers them, and if, therefore, the cerebrum contains two grey masses of different morphological value—at any rate, OUR IDIOT'S BRAIN PROVES THAT THE CORPORA STRIATA ARE NOT SUBSERVIENT TO THE CORTEX.

I am aware that it would be in accordance with the past history of the treatment which the brain has received to escape from the conclusion just formulated by supposing that the corpora striata, although normally the servants of the cortex, may, in its absence, assume higher functions and vicariously take its position; but this is a subterfuge too preposterous, as it appears to me, to be seriously discussed. Only our ignorance of the real structure and functions of the different parts of the brain, and the mystery which in consequence enshrouds it, would induce any one to hazard such a suggestion. The structure of the corpus striatum is very different from that of the cortex taken as a complex whole. The same elements may be found in both, but some of those found in the cortex are absent from the corpus striatum, and certainly the arrangement of different elements found in the former is in no way represented in the latter. Although we know nothing of the value of these peculiarities of brain structure we do know, at any rate, from our experience of the body at large, that they indicate a wide diversity of function.

If Wernicke's theory that the corpus striatum is an involuted portion of the cortex, and my theory that the optic thalamus belongs to the central grey tube be adopted, the following question will necessarily present itself to us:—Are there any portions of the central nervous system which belong neither to the central grey tube, which consists of the primary metameric centres of the nerves, nor to the peripheral grey tube which contains

elements of the connections of which we know little, except that they are not primarily or directly united with either afferent or efferent nerves?

For a long time the central nervous system has been viewed as consisting of three strata of grey matter connected together by two sets of white fibres. (1) There is the grey matter of the cord and medulla, which receives the fibres of all the peripheral nerves except the first and second, and is connected by means of the white matter of the cord with (2) the corpora striata and optic thalami, which "basal ganglia" are again connected with (3) the cortex by means of the corona radiata.

Flechsig has shown by embryological methods, and numerous observations, pathological as well as anatomical and experimental, have placed the matter beyond the possibility of doubt, that a considerable portion of the fibres from the cortex pass through the internal capsule to the crura without forming any connections with the "basal ganglia." Wernicke has contended, and all appearances are in his favour, that *none* of the fibres that travel from the cortex into the crura are broken in the corpus striatum (nucleus caudatus). It is impossible, therefore, that Meynert's projection scheme can hold absolutely, and be the only expression of the relation to one another of the several constituents of the central nervous system, and, for my own part, I feel compelled to secede from this, which has hitherto been the dominant view as to their relationship. It is necessary, however, to consider whether the allocation of the corpora striata to the cortex system, and of the optic thalami to the central grey tube, makes it necessary for us to abandon the conception of a tripartite plan in the arrangement of the elements of the central nervous system, and replace it by the conception of a dual plan. Are there no other grey masses which may be looked upon as nodes between the cord and the cortex?

Psychologists have demanded a halting place for both sensory and motor impulses. It is my contention, however, that the varieties of reflex action would be no easier to classify were such a view of the constitution of the system borne out by anatomical evidence. Further, I maintain that every entering and issuing nerve-fibre has a primary centre (connection with a cell, process-felt-work, or what not) in its own metamer, and that all the grey

matter which is developed immediately beneath the epithelium lining the central canal, and its dilatations into the three cerebral vesicles, is required to afford sufficient material to allow of this plan being carried out. I therefore find the system to separate naturally into *two parts, the one developed on the inside, the other on the outside of the involuted epiblastic tube*. The one comprising all the grey matter of the cord, medulla (exc. the olives), pons, mid-brain around the aqueduct of Sylvius, and fore-brain on the sides and floor of the third ventricle; the other the cortex of the cerebellum, corpora quadrigemina and cerebrum. The former connected with the peripheral nerves, the latter connected with the former by the white fibres of the intermediate zone. The central grey tube, the first to arise in the vertebrate sub-kingdom, and found in every metamer of the body, from the anterior cerebral vesicle which belongs to the præoral segment to the sacral cord, the peripheral grey tube increasing in size and complexity as we ascend the animal scale.

In each system numerous commissural fibres are to be found connecting its several parts. It is not possible on anatomical evidence to assert that no fibres pass directly from sensory nerves to cortex without interruption at the central grey tube, although it is quite justifiable to make a similar assertion with regard to the relations to the cortex of motor nerves. Complications have arisen in the connections of the optic and olfactory nerves, owing to the peculiar mode of growth which they have adopted, which bring them apparently into immediate connection with the cortex. I shall hope to show, however, later on, that an immediate connection does not actually exist, for a portion of the substance of the central grey tube has become detached and lodged in the retina and olfactory bulb. These nerves arise as hollow outgrowths of the anterior cerebral vesicle. Into their vesicles the epithelium lining the primitive neural canal is prolonged. Immediately outside the epithelium is developed, in the olfactory and optic vesicles as elsewhere, the grey matter of the central tube. A portion of this tube is thus located peripherally in the olfactory bulb and retina. The olfactory and optic nerves still have their primary centres in the grey matter lying on the sides of the third ventricle (the optic thalami), but

their connections with the cortex *via* this grey matter are obscured by the presence peripherally of some of the elements which elsewhere are incorporated with it. The fact, however, that these two nerves are formed as hollow outgrowths shows that we have to do with secondary adaptive processes. These nerves are not *par excellence* parts of the brain. All the nerves of special sense were, I imagine, originally branches of segmental nerves, distributed to sense organs, arranged in series, one to each segment, and in the vertebrate prototype of equal low value. They arose, it is needless to remark, as processes of the cells of the central grey tube, the peripheral tube which is confined to the anterior dilatations of the neural axis not being then in existence. As the sense organs at the anterior extremity of the body grew in size and in structural specialisation, it was found advantageous, for the sake of their better nutrition and more immediate connection with the brain, that they should arise as hollow outgrowths. The optic nerve remains in its original position with regard to the fore-brain, and has returned in constitution to a solid bundle. The olfactory nerve remains in the condition of a hollow outgrowth, perpetuating thus a stage through which the optic nerve has passed. Certain elements, however, which are elsewhere found in the ganglia of the posterior roots, and in the aesthesodic region of the cord, remain in the retina, as in the olfactory bulb, at a distance from the rest of the central grey tube. The olfactory nerve, as shown by Marshall,¹ is first to be seen arising in quite normal fashion from the anterior cerebral vesicle. By a secondary process, however, it becomes involved in the margin of the cerebral mantle. Possibly it actually comes to form a part of the prosencephalon, although this is not by any means such a matter of certainty as is generally supposed. There is no need, however, to call it a "rhinencephalon," for it is no more a part of the brain than is the optic nerve.

In order to make clear the relation of the olfactory and optic to other nerves, it will be necessary to discuss for a moment the nature of the elements found in their peripheral organs, the retina and olfactory bulb, which appear at first sight to mark them off as of different morphological value.

¹ *Quart. Journ. Micros. Science*, July 1879. See also Balfour, *Comparative Embryology*, vol. ii. pp. 336 and 382.

It is very generally recognised that of the several layers which constitute the retina, the layer of rods and cones with their nuclei (in the outer nuclear layer) are of epithelial, the other layers of neural standing. This position was first adopted by Kölliker, and appears to be unassailable. The fact that in the case of the organ of vision the terminal elements are derived (in higher animals) from the involuted epiblast, while those of all the other sense organs are derived from general epiblast, as well as the fact that this transposition actually occurs in invertebrata, shows us that general epiblast and involuted epiblast differ from one another by very little in value.

The nervous elements of the retina are arranged in three strata—the inner nuclear, inner molecular, and ganglion cell-layers respectively. The nerve filaments, therefore, which commence in the epithelial elements, are—(1) connected with the bipolar cells of the inner nuclear layer; (2) they break up in the reticulum of the molecular layer from which are derived the processes of (3) the ganglion cells. In each ganglion cell a number of grey filaments are associated to pass to the brain in a single medullated fibre of the optic nerve.

Although I have not yet published in detail the observations upon which my conclusions are based, I have asserted, in my thesis already referred to, that the same elements are to be found in the olfactory bulb as in the retina, and that they are similarly arranged. The filaments derived from the cells of the olfactory epithelium, which in many animals—the Triton, for example—so closely resemble the rods and cones with their nuclei of the retina, pass—(1) into the bipolar cells with conspicuous round nucleolated nuclei of the stratum granulosum; (2) break up in the reticulum of the stratum gelatinosum; (3) are associated by the cells of the stratum vesiculosum into the fibres of the external olfactory root, which is the true olfactory nerve, as far as homology with the only similar nerve the optic is concerned.

The analogy between the olfactory bulb and the retina, as shown in their development, has been remarked by Luys and Meynert, but the exact homology of their several strata, and the identity in the connections of the olfactory filaments, have, as far as I am aware, not been hitherto suspected. In both cases

a bipolar cell is first inserted in the course of the filament, then the filament breaks up into a nerve reticulum, from which are again derived the basal processes of the ganglion cells. In the case of the olfactory nerve, this process is not entirely restricted to the bulb, but goes on also to a certain extent in the hippocampus.

My view of the connections of ALL SENSORY NERVES with the central nervous system is that they UNDERGO IN THE FIRST INSTANCE THIS THREEFOLD INTERRUPTION—(1) IN BIPOLAR CELLS; (2) IN RETICULUM; (3) IN MULTIPOLAR CELLS.

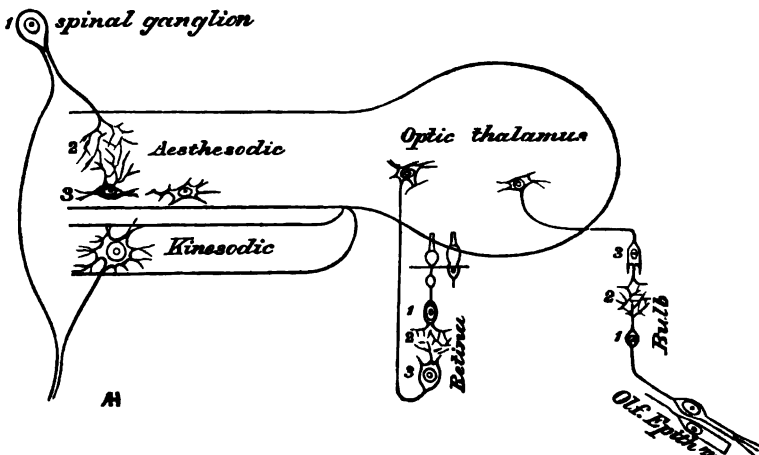


FIG. 3.—Diagram of the anterior part of the central grey tube, indicating the relation of the optic thalamus to the grey matter of the cord. The aesthesodic portion of the grey matter is represented as lying above, the kinesodic portion below, the central canal. The sensory fibres of a spinal nerve, after their connection with a cell of the root ganglion, pass into the substantia gelatinosa Rolandi, in which they break up into a reticulum. From the reticulum, fibres are collected by the multipolar cells of the posterior horn. In the case of the first and second cranial nerves, reticulum and multipolar cells, as well as bipolar cells, are situated at a distance from the brain in the olfactory bulb and retina respectively.

In the cord and medulla the substantia gelatinosa Rolandi appears to me to have exactly the same constitution as the substances termed molecular and gelatinous in the retina and olfactory bulb. Further, the cells of the ganglia on the posterior roots are in fishes bipolar and very similar in appearance to the bipolar cells of the nuclear and glomerular layers, and it appears

to me obvious that in fishes at any rate the sensory fibres of the spinal nerves, after passing through a bipolar cell, break up in the abundant substantia gelatinosa, from which are again derived the processes of the cells of the posterior horn. In the lower members of the vertebrate series, therefore, the difference between the first two and succeeding nerves is merely in the position of the elements of the central grey tube which belongs to them.

That a uniform plan should be adopted for all sensory nerves, and throughout the whole vertebrate sub-kingdom, appears to me in the highest degree probable; but at present at any rate the cells of the spinal root ganglia are difficult to place in proper relation to the sensory nerves. That they are connected with the fibres of the root on either side of them appears to me to be placed beyond all doubt by the results of section. *A nerve fibre only dies when it is cut off from the cell of which it is a process.* As is well known, in whatever part the root is cut, those portions of the sensory fibres which remain in connection with the ganglion retain their vitality—the others die.

The nature of this connection is not properly understood. By various observers the cells have been described as unipolar (or even apolar), and the view has been largely adopted that the fibres connected with them have a peripheral course only—a view which appears to be *prima facie* absurd. We have no analogy for supposing that fibres may commence in ganglion cells and course away from the central system, nor can we conceive of the use of such an arrangement. Various attempts have been made to settle this question by counting the fibres on each side of the ganglion, but such observations have yielded contradictory results owing to different animals being used. In some animals a condensation of sensory fibres certainly occurs at the ganglion—more fibres being connected with it peripherally than centrally. Nor are the fibres connected with the cells small, sympathetic, vasomotor, trophic, or what not, but large, medullated, sensory. Again, although I have not attempted to compare exactly the number of the cells in the ganglion with the number of sensory fibres in the root, the former do not appear to me to be less numerous than the latter.

Rawitz¹ has shown that the discrepancies in the accounts of

¹ *Archiv für Micros. Anat.*, xxi. p. 244.

the form of the ganglion cells depend upon the differences in different animals. In cartilaginous fishes they are bipolar, in all higher animals unipolar.

Ranvier¹ described a T piece, which, leaving the single pole of the cell, rested upon the sensory fibre. Retzius² corrected this observation by showing that the two limbs of the T are in reality its dichotomous branches, and that one is the sensory fibre coursing peripherally, the other its central connection.

Whatever may be the exact plan according to which the fibres of the sensory nerves are connected with the cells of the root-ganglia, the existence of a direct connection appears to me indubitable. The simple arrangement which obtains in the fish (and the assumption of Rawitz³ that the root-ganglia of fishes are not homologous with the root-ganglia of higher vertebrates appears to me most unjustifiable) is modified in the cases of the first two nerves in this particular, that instead of the bipolar cells alone being found outside the central axis (in the root-ganglia), a portion of the reticulum, and some of the associating cells, are also peripheral in situation. That is to say, that, while in the case of a spinal nerve, the bipolar cells lie in the root-ganglion, the reticulum (substantia gelatinosa Rolandi) and the ganglion cells in the posterior root, all three sets of elements are peripherally situated in the retina, in the inner nuclear, inner molecular, and ganglion cell-layers respectively.

The peculiar mode of outgrowth of the first two nerves, of course, alters considerably the relation to one another of the two grey tubes at the anterior extremity of the body. The optic thalamus is the anterior termination of the posterior cornu of the cord. It contains, however, only the remnants of the substantia gelatinosa Rolandi, for although, as elsewhere, in the central grey tube, this is a conspicuous part of it during its development (Löwe⁴), and is permanently represented in the "centre médian" of Luys, it is largely replaced in the adult by the molecular and gelatinous layers of the retina and olfactory bulb respectively. Again, this accounts for the fact that although

¹ *Comptes rendus*, 1875, No. 25.

² *Archiv für Anat. und Physiologie*. Anat. Abth. 1880.

³ *Loc. cit.*, p. 285.

⁴ *Beiträge zur Anat. u. Entwick. des Nervensystems*.

the optic and olfactory nerves first grew out as processes of the cells of the optic thalamus, and although, therefore, the thalamus must permanently remain their primary centre, it is not impossible that these nerves have also direct cerebral connections. The cells of the thalamus are no doubt very largely concerned in receiving the commissural fibres, which connect the centres of the first two with the centres of all other peripheral nerves.

In the latter part of this paper I have digressed somewhat from the subject immediately in hand, but the train of thought here followed, and the intercurrent researches to which it has given rise, appear to me to be the necessary results of the consideration of the deficient brain, which forms the subject of the paper.

THE FACT THAT IN THIS BRAIN NO DIMINUTION IN THE SIZE OF THE CORPORA STRIATA IS ASSOCIATED WITH CORTICAL DEFICIENCY PROVES THAT THESE GREY MASSES ARE NOT SUBSERVIENT TO THE CORTEX. TO WHAT PART OF THE SYSTEM DO THEY THEN BELONG? MANY CONSIDERATIONS POINT TO THEIR BEING OF THE SAME MORPHOLOGICAL VALUE AS THE CORTEX. IF THEN THE OLD GROUPING OF OPTIC THALAMUS WITH CORPORA STRIATA IS BROKEN DOWN, WHAT IS THE POSITION OF THE FORMER MASS? IT CONTAINS THE PRIMARY CENTRES OF THE FIRST TWO NERVES, AND CONSTITUTES THE ANTERIOR TERMINATION OF THE ÆSTHESODIC REGION OF THE CORD.

EXPLANATION OF PLATES XIX., XX.

PLATE XIX.—*A*, Basal view of the brain of the hydromicrocephalous idiot; *B*, lateral ventricles of the same brain; *C*, body of the idiot, showing the customary attitude and position of the limbs; *D*, section cutter described on p. 365.

PLATE XX.—Three typical sections. Section 28, as shown by the cross line in fig. 1, p. 367; it is through the anterior end of the right nucleus caudatus, NC, the convex anterior surface of which has just been cut off, and the solid grey nucleus exposed. Section 39, between 38 and 40, and section 45, between 44 and 46 on the same figure. The lettering on the plate is self-explanatory.

DR ALEX. HILL.

APPENDIX TO DR HILL'S PAPER.
NOTES OF CASE OF H. C. S., A CONGENITAL IDIOT, ET. 19
S. By S. E. DE LISLE, L.K.Q.C.P., L.R.C.S. I., *Senior*
and Officer of the Three Counties Asylum, Arlesey.

He states that he was apparently a healthy child when born, delivered naturally. At the age of eleven months he had an fit convulsions. He always seemed weak on his legs, and when ed to make him walk he merely put his toes to the ground, with unsupported immediately fell. The faculty of speech he acquired. When about a year and a half old they began to he was blind, although his eyes presented no abnormal ances.

He heard voices and other noises he seemed to hear and identify. When about two years old it was noticed that there was a "skedness" about his knees. They appeared to be drawn up rds his abdomen. Not being able to walk, he was generally ed in the arms of his mother. He did not seem to be able to use right arm; the left he could move freely. At five years of age it was observed that his pelvis was deformed, and his lower extremities had a tendency to remain drawn up towards abdomen. He seemed conscious at this time of persons addressing n, but exhibited no signs of understanding what was said. When food was presented to him, he would, as if guided by the sense sm-ll, open his mouth wider than usual and allow it to be poured own his throat, making little or no movement of his lower jaw. His food was generally of a liquid or semi-liquid character. At times he artook of more solid food, which, however, he bolted ravenously, and ever attempted to chew.

In this condition he continued up to the time of his admission into the asylum, save that as he grew older his thorax developed in size and his extremities increased in length. The deformity of his pelvis and extremities yearly became more apparent, and his limbs became fixed in the position in which we found them.

At no time did he control his evacuations, and his general state was either being carried in his mother's arms or lying in bed.

He knew his mother's and grandmother's voices, and when spoken to would turn his head in the direction whence the sound proceeded. He would not take his food save from one whose voice he seemed to know.

The alleged cause of his being sent to the asylum was that he had become very noisy and unmanageable, and refused his food.

He was admitted on the 29th July 1882, and was considered to be a congenital idiot. He was in poor bodily condition, and abrasions of

I have no accurate information as to his sight previous to this, but it is thought that he was always blind.

skin were noticed on sacrum, buttocks, and ankles. The right knee was swollen.

Some measurements were taken—

	Inches.
Head—Circumference,	18½
„ From ear to ear opposite to external auditory meatus,	11
„ From root of nose to occipital protuberance,	10½
„ Across forehead,	5½
„ From tip of chin to top of forehead,	7½
„ From line drawn from tip of acromion to vertex of skull,	10
Thorax—Circumference round mammæ,	29
Pelvis—Circumference round anterior superior spines of ilium,	22
Length of arm, about	13
„ fore-arm, about	9
„ hand, about	7½
„ thigh, about	14
„ leg, about	13
„ foot, about	6½
Circumference of arm,	5
„ around middle of thigh,	7
„ of calf of leg,	5½

Genitals were fully developed.

As he lay in bed his length was about 2 feet 8 inches; had his limbs been extended he would have been about 5 feet.

A correct idea of his deformities could only be obtained from a photograph (Plate XIX., C).

His limbs were fixed in the flexed position—palate arched and cleft. Teeth convergent and notched. There was very little movement in the lower jaw.

He was an illegitimate child. His father promised to marry his mother, but subsequently refused and deserted her. She was much depressed in consequence while she was carrying the child. There is no history of syphilis, epilepsy, or drink on either side. The mother is apparently a healthy woman, has since married, but has had no children.

After he came to the asylum he seemed as if he missed some one or something, refused his food, and made a constant discordant noise. In a week or so he seemed to become accustomed to his attendant's voice, and then took his food more freely. The attendant would say to him, "Now, Harry," the boy would open his mouth, just as young birds may be seen in a nest, gaping when their mother brings them food, receive the contents of the spoon or feeding cup, and without any apparent effort of deglutition, the food disappeared. There seemed to be no interference with the larynx, and there was no movement of the lower jaw. His attendant remarked to me, and not without reason—"It's like pouring water down a pipe, sir."

His food consisted of milk and beef-tea thickened with eggs, arrowroot, &c.

His eyes were constantly open, either staring vacantly or rolling from side to side; so continuously were they open that his night-attendant said "he slept with his eyes open."

He could recognise light, as I have at night passed a lantern across his eyes, and have noticed that he would turn them in whatever direction the light might take. At such times occasionally a smile would pass over his face.

When his mother visited him in the asylum and spoke to him, he seemed to recognise her voice.

When he was "wet" or "dirty," he always cried out and would not cease until he was changed. He required constant care and watching, like an infant.

His attendant, noticing that he made use of his left arm,¹ placed a small stick in his hand; this he used to knock against the top of his bed for hours consecutively; were the stick taken from him he would immediately begin to cry. If he were crying, and the stick were placed in his hand, he would cease and appear pleased.

About two months previous to his death, he began to refuse his food, and had repeated attacks of diarrhoea.

The disease in his knee-joint increased, and, despite all efforts to stay it, an opening came into the joint. The abrasions on sacrum, buttocks, and ankles turned into suppurating sores, and there was a copious discharge of pus from these places. He now vomited his food, his ankles became cedematous, his strength rapidly failed, and he died quietly on the 1st January 1883.

¹ I have dissected both arms, but failed to find more than a slight difference of development between the two sides. In no part of the body was there any evidence of arrest of development. The muscles were small, but all present and of normal texture. The nerves did not appear to me smaller than they usually are in a man of his size. As noted above, some of the joints were diseased; the movements of all the others were limited.

ON THE CORPUS CALLOSUM IN THE ADULT HUMAN
BRAIN. By D. J. HAMILTON, M.B., *Professor of Pathological
Anatomy, University of Aberdeen.* (PLATES XXI. XXII.)

THE following paper comprises an account of the origin and destination of the callosal fibres of the brain in the adult. The subject is one on which I have now been engaged for many years, but, with the exception of a brief communication to the Royal Society, of date February 23, 1884,¹ I have refrained from publishing an account of my researches for two reasons—1st, because I was unwilling, although I have long been persuaded of the truth of the facts, to rush into print with views which to many might seem too heterodox in their character to be entertained in the absence of overwhelming confirmatory data; 2nd, because, however convincing the evidence in support of these views may have been, as derived from the examination of the adult brain, it could never be conclusive until confirmed in the embryo and by other means of investigation. It is only lately that I have had leisure to undertake the study of the embryonic corpus callosum, and now, having found in it sufficient evidence to confirm what exists in the adult, I have thought it proper to place the main conclusions at least on record, leaving any deductions from them to the future. I would have it understood, however, that the following is not a complete exposition of the subject. It would be useless to go into details too minutely, unless a greater amount of illustration were available than is practicable in a journal such as the present, and, even in this somewhat superficial account of the vastness of the callosal connections, I fear the description may suffer for the above reason. I hope at some future time, however, to give a fuller account of the whole subject than is possible at present.

INTRODUCTORY.

The almost universal idea at the present day is that the corpus callosum is a commissure—that it is composed of fibres

¹ *Proc. Roy. Soc. London.*

which run between the two hemispheres, thus uniting their cortical centres, and so bringing corresponding areas on the two sides into functional harmony. It is held that the fibres, which concentrate in the corpus callosum from the cortex of one side, spread out in a fan-shaped manner in the opposite centrum ovale, and ultimately become attached to parts of the cortex corresponding in situation to those from which they have arisen. The corpus callosum, it is said, belongs to the great "association" system of fibres, by which the functions of one cortical centre are correlated with those of another. It is the inter-hemispherical commissure of the upper half or two-thirds of the brain; while the anterior commissure fulfils a similar purpose between parts nearer the base.

Such a theory, at first sight, seems very plausible, and indeed it has met with almost universal acceptance of late years. It has no doubt arisen from the appearance presented by the corpus callosum on separating the hemispheres. Its fibres are seen apparently running transversely, or nearly so, on the surface. They pass into the hemispheres on each side, and are lost to view. It has even been said by Meynert that he has seen individual fibres, in transverse sections, go across continuously from one cortex to that opposite. How this is possible I cannot conceive, because, on the most superficial examination of a properly-prepared section of the brain, it is self-evident that the fibres do not lie in the same plane, but that in their transverse course they intertwine, and, as I shall show, decussate in the most complicated manner. If one only considers for a moment what such a statement means, the uselessness of attempting to ratify it will be apparent. It means that a fibre may continue to run in the same plane from side to side without diverging more than a fraction of a micromillimetre. The mere fact that the brain is never exactly of the same size on both sides would preclude the possibility of seeing such a fibre, and, as a matter of experience, I have found that, cut a perpendicular transverse section as symmetrically as possible, the parts on the two sides never exactly correspond. One of the first notions to be got rid of in studying the corpus callosum is that of supposing it to be possible to trace a single fibre continuously from one cortex to the other, or indeed past the middle line. It is only

by following out the fibres *in the gross*, so to speak, that their origins and destinations can be approximately arrived at, and the difficulty of accomplishing even this, it will be found, is much greater than might be supposed.

Against the commissural theory there are several very blatant facts, which, until satisfactorily explained, should make one hesitate in accepting it as proven. If the one cortex is so intimately bound to the other by this huge mass of white matter, why is it that a destructive lesion on one side does not affect the corresponding region on the opposite? We know that the greater part of one hemisphere may be destroyed in adult life without there being any participation of the other, but if such an intimate connection does pertain between the two, we ought surely to anticipate some sympathetic alteration in its bulk. It may be replied, that if the brain is fully grown such a response of the one side to a destructive injury of the other is not necessarily to be expected. The parts are already formed, and the callosal fibres are not subject to the ordinary laws of atrophic degeneration. This argument is conclusively disproved by the fact, that in childhood, while the brain is still growing, a partial destruction or microcephalic condition of one hemisphere does not materially influence the bulk of the opposite. Through the kindness of Dr Reid, of the Aberdeen Asylum, I some time since came into possession of the brain of an imbecile woman over fifty years of age, in whom the cortex of the first and second frontal convolutions was entirely destroyed. She had been imbecile from infancy, and, from the state of the arteries, it seemed as if their occlusion (probably syphilitic) had been the cause of the deformity. The opposite frontals, however, were of natural size, and did not exhibit any marked deformity or aberration from the normal, as one might expect in such a case. Many other instances of the same phenomenon are familiar to every pathologist, so that here we have one set of facts, which, if they do not disprove the commissural theory, at least militate against it. For if the callosal fibres are simply commissural and represent the processes between nerve cells situated in opposite hemispheres, we have to face the problem naturally ensuing from such a case as I have mentioned, namely, whether it is possible for nerve processes to continue to

exist unimpaired while their nervous connection on one side is destroyed, and when they have been functionally inert for so many years? I do not deny the possibility of this, but simply suggest that until it is settled in the affirmative, we ought to pause before accepting the commissural theory as it is generally understood.

A second serious objection to the commissural idea is that, physiologically, destruction of one side of the brain does not interfere materially with the functions of the opposite. That is to say, after destruction of the motor or sensory centres on the one side, the functions of the opposite are not necessarily thrown out of gear, or even materially disturbed, unless where, as in the case of the optic nerves, a partial decussation exists in their peripheral fibres. The facts of aphasia might lend some support to it, but, even here, the whole phenomena may be explained by a partial decussation taking place in the fibres coming from the aphasic centres, before their entrance into the trunks of the oro-lingual nerves. This, I think, considered in the light of what we know of other motor paths, seems very likely, and would explain the *paretic* state of the muscles in ordinary aphasia from a one-sided lesion. I hope presently to show that the anatomical substrata of aphasia are much more complicated than is generally supposed.

Another argument still against the theory that the corpus callosum serves to combine the functions of the two sides by acting as a commissure between cortex and cortex, is that animals which do not possess a corpus callosum, or in which it is rudimentary, are capable of combined action just as much as those which do possess it.

The commissural notion regarding the corpus callosum has, however, not found favour throughout all time in the eyes of anatomists, and, curiously enough, some of the older anatomists, such as Willis and Steno, have taken quite a different view of its significance. Willis, in his dissertation on the anatomy of the brain,¹ has the following passage regarding it:—"Cerebrum hujusmodi Anfractibus quasi liris et sulcis exaratum, in medio diffinditur, ac veluti in *duo Hemisphæria* dirimitur; utræque tamen medietates conveniunt, et quasi fundantur in

¹ *Opera omnia*, p. 6, Amsterdam, 1683.

substantia similari albissima, quae totam cerebri molem interius obducit, ac quasi concamerat. Haec durior quam alia quævis cerebri portio existit; cumque omnia medullaris fuerit, omnes omnium Anfractuum medullas in se recepit, iisque tanquam baseos communis loco est. In utroque cerebri Hemisphærio, circa partes anteriores hoc *corpus callosum*, sive substantia medullaris, supra quam in alio quovis loco longe crassior et spissior evadit; atque ibidem medullæ oblongatæ apicibus utrobique affigitur; ab istis apicibus tanquam ortu suo, medullaris hæc substantia cerebrum obducens, et concamerans, versus posteriora expanditur, ac sensim in crassitie minuitur; demum hujus expansi limbus exterior arctius contrahitur ac inferius medullæ oblongatæ caudici (uti modo innuitur) membranorum et vasorum nexu conjungitur." Although the ideas of the structure and functions of the brain in Willis' time must have been very crude, yet from the above quotation it is evident that he did not regard the corpus callosum as an inter-hemispherical commissure in the sense in which the term is employed at the present day, but rather as a meeting point or decussation of the peduncles of the medulla oblongata, from which fibres radiated into the surrounding medulla of the hemispheres.

Foville, in his atlas,¹ has some very remarkable drawings of the corpus callosum. Allowing for a certain amount of artistic license in their production, it is nevertheless perfectly evident that he had seen appearances which I believe are not artificial, and which are deserving of much more attention than they have met with. He made the preparations from which the plates were taken by inserting the finger between the corpus callosum and gyrus fornicatus, and drawing it roughly backwards and forwards. The cerebral mantle has then been drawn aside, and the corpus callosum exposed. In the whole of these drawings it will be noticed that on each side the callosal fibres arch at first pretty acutely upwards, and subsequently turn downwards towards the situation of the inner capsule. As I hope to show, this course of the callosal fibres on each side is what actually exists, and is no mere creation of the

¹ *Traité complet de l'Anatomie*, &c., 1844, first part, pl. xv., pl. xvi. fig. 2, pl. xvii. fig. 1, and pl. xix. fig. 1.

anatomist. Foville used to be called a "fanciful" anatomist, and his work has been rather despised in this country. However fanciful he may have been, I can confirm by other methods of manipulation what he has figured touching the course pursued by the callosal fibres.

Gratiolet, in his work on the Nervous System,¹ expatiates on the beauty of Foville's demonstration of the corpus callosum, and says that he has been able to reproduce, by the same procedure, exactly what Foville described and figured in the brains of man and mammals. His words are the following (p. 175):—"J'ai vu exécuter et j'ai pu reproduire, à mon tour, la préparation de M. Foville et, sauf le point dont j'ai parlé, le résultat qu'on obtient avec lui est incontestable. Ainsi, suivant le mode de préparation, le corps calleux est tantôt une commissure transversale entre les deux hémisphères, et tantôt une voûte unissant, en un même système, les deux couronnes radiantes." He thus regards the corpus callosum as composed of two separate systems of fibres, the one comprising those bundles passing from the corona radiata to the opposite hemisphere, the other those fibres passing from cortex to cortex between the two hemispheres. Through the corpus callosum, in this way, the one hemisphere would be placed in communication with the opposite side of the body.

These researches of Willis, Foville, and Gratiolet were conducted in a very rough manner, so much so, that anything like clear proof of their assertions could never be obtained. Still I hold that undoubtedly they have foreshadowed the truth; and although the result has been only an approximate to the whole truth, yet it forms an indication that they had been led to suspect that the supposed commissural nature of the corpus callosum is doubtful. Up till the time when I made out the following facts, I was unaware of what the anatomists just referred to had written on the subject, and it was all the more pleasurable to find afterwards, on inquiring into the matter, that they had proceeded so far in the same line of inquiry as myself, and that their conclusions, in part at least, coincided with my own.

Methods Employed.—Perhaps it might be thought proper that I

¹ *Anatomie comparée du Système Nerveux*, 1839-57, vol. ii.

should explain the *technique* of the methods I employ before detailing the results of the inquiry. To this I may reply that I have resorted to almost every available means of getting at the course of the callosal fibres, so far as macroscopic, microscopic, and (if I may be allowed to coin a word to express another method of examination) *mezzoscopic* examination goes. The *technique* of the *mezzoscopic* part of the investigation I have already recorded in *Brain* for July 1883. I still adhere to the procedure described in that paper, with some minor alterations, which render the various stages of the process simpler, and which afford much better results. The principle, however, of the process is alike, namely, that of the enlargement and definition of sections of the entire brain by the action of gelatine and potash. The preparations obtainable by this process are of extreme beauty, and far excel in definition those prepared by any other means with which I am acquainted. As just said, the process has the effect of stretching the section of brain substance to a much greater size than it normally possesses; that is to say, from a third to twice its original dimensions, so that when examined with a simple lens the course of most of the nerve tracts can be followed with great accuracy. The sections require to be made through the entire organ, a preparation of one part only not being sufficiently demonstrative of the mutual connections of surrounding parts. They must be made in different planes, and each must be labelled at the time it is cut, so that the whole series can be replaced in proper order. The process took me several years to evolve, but the results are so satisfactory that I do not grudge the time expended upon it.

It must, however, be remembered that it is not from one brain that final conclusions are to be drawn. For various reasons several must be employed, even when the plane of section is alike. These are chiefly, first, that in order to place the segments of brain tissue in the freezing microtome they must be cut from half an inch to an inch thick, and consequently at the various points of section there must always be some deficiencies in the series. A second reason is that the slightest alteration in the antero-posterior axis of the brain in cutting these gross segments causes very considerable divergence in the appearance of the future sections. As illustrative of this I may refer to the

variability in the appearance of the band of Vicq d'Azyr. It can hardly be recognised as the same structure when only a very slight deviation is made in the position of the antero-posterior axis of the brain in cutting pieces of proper thickness for introduction into the freezing microtome. At one time it is seen as a thin band cut cross-wise; at another it appears larger from being obliquely cut; while in a third its whole course is displayed from the corpus albicans upwards. Cut two brains as accurately as one may into, say, eight or ten equal-sized segments, in exactly similar localities, there will be none of the corresponding cut surfaces in the two quite alike. Hence to draw fair and just conclusions it is necessary to have a large supply of brains at command, prepared by different methods, in accordance with the particular object to be aimed at. I shall begin the description of the corpus callosum with the macroscopic examination.

The Callosal Tract as seen with the naked Eye.

If a *fresh* human brain be cut transversely in a perpendicular plane the corpus callosum is seen to be simply a white mass of medullary substance stretching from one hemisphere to another, and a very short way external to the point where the gyrus fornicatus and it abut upon each other, it is impossible to trace its further course into the centrum ovale. Its fibres have an obscurely radiating appearance, but nothing further can be made out of it. For the purpose of description, I shall call that portion of it which is usually designated the "corpus callosum," that is to say the part which bridges over the ventricles, the *tectorial part of the callosal tract*. It is only, therefore, the tectorial part of the callosal tract which is clearly visible, the subsequent course of the fibres as they enter the cerebral white matter on each side cannot be traced. The fibres of the centrum ovale are so closely interwoven and so highly medullated that the isolation of any one tract from the others becomes in the adult a practical impossibility. It is evident, therefore, that if we wish to follow out the distribution of the fibres of the callosal or any other band, some means must be resorted to in order to render these apparent.

If the brain be hardened in spirit, no further definition of the

medullary white takes place, and the organ becomes so shrunken and altered in shape and contour that it is of little use for minute observation.

When Müller's fluid, however, is employed, and especially, in the case of the human brain, *when it is injected from the large vessels at the base*, the size and contour, in the first place, are retained, and the differentiation of some parts of the medullary white matter becomes most beautiful. The great secret in getting the fluid to penetrate is to inject it. I do so from the two internal carotids and one vertebral immediately after the organ is removed, and repeat it on two other occasions with an interval of a couple of days between them. The brain does not shrink, and after it has lain for three weeks in a large excess of the hardening solution, it becomes so tough that it can be handled with impunity, and can then be cut into thick slices in the particular direction required. When these are soaked in my freezing fluid,¹ frozen, and polished on the surface by means of the section blade, the following appearances are to be found—not so well on the section cut as on the surface of the frozen piece of uncut brain substance.

Suppose, to begin with, that the plane of section has cut transversely through the brain in the middle of the knee of the internal capsule, the parts exposed will be very much the same as those figured in Plate XXII. The drawing represents the anterior part of the knee, and, consequently, the surface of the segment I have supposed would show the parts a little behind this. The parts figured, however, pretty closely correspond to what would be seen, and will serve for the purpose of illustration. It must be understood that the drawing was taken from a preparation mounted by my gelatine method; but the situation of the parts is of course the same as on the surface of the segment, and it will greatly aid in understanding the description if this plate is utilised for the purpose of reference. The convolutions which are cut through, in the first place, are the upper two-thirds of the ascending frontal (*As. Fr.*), and a piece anteriorly of the lower third of the ascending parietal (*As. Pr.*). The temporo-sphenoidal lobe (*T. S. L.*) behind its free anterior extremity also comes into view, and on the inner aspect of the

¹ *Brain, loc. cit.*

hemisphere is the gyrus fornicatus (*G. f.*). The plane of section lies a little behind the fifth ventricle, but the two laterals (*L. V.*) and the third (*III. V.*), with the intercommunication between the two—the foramen of Monro (*f. M.*)—are cut across. The parts of the basal ganglia which are brought into view are in the first place the middle of the caudate nucleus (*C. N.*), two divisions of the lenticular nucleus (*LN₁* and *LN₂*), the anterior tubercle or nucleus of the thalamus (*Th.*), the claustrum (*Cl.*), with the outer capsule (*O. C.*), and the white substance of the island (*w. s. I.*) on either side of it; while lying most externally is the island of Reil itself (*I. R.*). Interposed between the caudate nucleus and thalamus on the inside, and the lenticular nucleus on the outside, is the inner capsule (*I. C.*), whose fibres it will be noticed run in large numbers into the thalamus (*Th.*). The tectorial part of the corpus callosum is shown at *C. C.*, while on each side of it is the medullary substance of the hemisphere.

Now, when such an opaque segment as I have described is polished as directed, the corpus callosum is seen passing into the white substance, but in place of its fibres losing themselves indefinitely in the mass of the centrum ovale, they are noticed to form an arch which passes upwards, outwards, and downwards, and finally terminates in the inner and outer capsules. The drawing (Plate XXII.) was taken, as before said, from a clarified preparation, and in it the boundaries and distribution of this arched mass of fibres are not so evident as in one which is opaque. But even in this transparent section, as illustrated in the drawing, its outline (*e.e.e.*) and connections were apparent enough to make them easily perceptible to the naked eye. I must especially emphasise, however, that, for reasons to be presently explained, this mass of fibres is more distinct on the polished surface of an ordinary opaque segment of brain, say $\frac{1}{4}$ to $\frac{1}{2}$ an inch thick, than in a thin section stretched by my gelatine method. This arch, formed by the fibres issuing from the side of the tectorial part of the callosal tract, varies in shape and dimensions in different parts of the brain. Thus, anteriorly, about the centre of the fifth ventricle, it is very obtuse superiorly, and turns round abruptly into the inner capsule, forming an almost complete semicircle. It measures in this neighbourhood, from

side to side, 10 mm.; while from above downwards—from the convex upper border to its entrance into the inner capsule—it measures 23 mm. In the mid-cerebrum, opposite the knee of the inner capsule, it reaches its greatest dimensions, measuring from side to side from the same points 15 mm.; and from above downwards, 28 mm. It is very broad at this point, and lies close to the grey matter of the cortex, the distance between its outer border and the grey matter being from 4 to 5 mm. Posteriorly its shape becomes markedly altered. The arch here is somewhat acutely pointed upwards, almost like the contour it has in the embryo. Opposite the splenium corporis callosi, it measures 16 mm. from side to side, and 20 mm. from above downwards.

As regards the extent of brain through which it is visible, it may be stated that it becomes perceptible a short way behind the commencement of the genu, and ceases to exist as a distinct arch immediately behind the splenium of the corpus callosum. It thus corresponds to the corpus callosum in position, becoming most evident opposite its middle part, and insensibly disappearing in front of and behind it.

Examined with the naked eye, or with a pocket lens, it is seen to be composed of dense bundles of nerve fibres, which, starting from the outer extremity of the tectorial part of the corpus callosum, curve upwards, outwards, and downwards towards the two capsules. The bundles as they enter the inner capsule become closely aggregated and much curved, and they are evidently shorter than those higher up (see Plate XXII., *h. h.*). This results from their having run obliquely to the plane of section.

When I first saw this arched system of fibres at each side of the corpus callosum, now several years since, I was extremely puzzled to know what it meant. I looked through all the books on the structure of the brain to which I had access, and examined their illustrations, but could not find it figured in a single instance, as exposed in a transverse perpendicular section, nor could I discover even the most cursory allusion to it. It was during this search that I came upon Foville's illustrations in the plates before enumerated, and, at the same time, found Gratiolet's description of the callosal fibres. The explanation of Foville's figures was now apparent. By introducing the finger between

the gyrus fornicatus and the tectorial part of the callosal tract (Plate XXII. *x. x. x.*), and tearing the medullary substance forwards and backwards, he had evidently separated this arched system of fibres from the rest of the medulla, and exposed it to view by turning back the cortical mantle. The contour of the fibres figured, as seen from above in the various plates referred to (*loc. cit.*), quite corresponds to its shape on transverse section, and it will also be noticed that he makes it coterminous with the anterior and posterior extremities of the corpus callosum. If the reader will turn up the first part of his Atlas, at plate xv., he will find a ridge of arcuate fibres, somewhat diagrammatically represented as seen from above, on either side of the corpus callosum at the letter L, which it seems to me must be the system I am describing. Foville no doubt was unaware of its great significance, and his drawings have almost entirely been forgotten, or deemed to be the outcome of an aberrant genius. There is a Latin proverb which says, "*Interdum stultus bene loquitur,*" and I think in this case that the kernel of truth contained in Foville's work on the corpus callosum has not met with that appreciation from anatomists and physiologists which it undoubtedly deserves.

What then is this enormous mass of fibres leaving the corpus callosum at each side, and curving downwards to the capsules? Without entering for the present into the arguments *pro* and *con*, I may state that my conviction is that it comprises the fibres which have come from the opposite cortex, which have crossed and decussated in the corpus callosum, and are now turning downwards to join the two capsules. And, accordingly, in order to distinguish this arched system of fibres (Plate XXII. *e. e. c.*) from the other parts surrounding it, I propose to give it the name of the **CROSSED CALLOSAL TRACT**. It commences at the point where the *tectorial* part of the corpus callosum enters the medullary substance of the hemisphere, and it terminates below at the upper extremity of the inner and outer capsules.

In a preparation similar to that which I have been describing, there is found coming down from the upper edge of the longitudinal fissure, and specially from the paracentral lobule, a *band of fibres* which bears a certain relationship to the *crossed callosal tract*. Throughout that part of the brain which corresponds in

position with the anterior and posterior thirds of the corpus callosum, its fibres incline almost entirely inwards towards the corpus callosum; but in the region opposite the middle third, part of its fibres curve inwards towards the corpus callosum, while some bundles from it also pass downwards directly to the inner capsule, and are lost in the dense masses which compose its substance. In their course downwards they mix with those of the crossed callosal tract; so that in a region which corresponds to the middle of Ferrier's motor area, the *crossed callosal tract* has intermingled with it certain bands of *direct* fibres from the cortex, and I think there can be little doubt that they are motor in their function. I shall revert to these fibres immediately.

The Mezzoscopic and Microscopic Appearances.

In order to study the further connections of the callosal tract in the adult, it is necessary to prepare the brain in thin sections, and to resort to the mezzoscopic and microscopic methods of examining these. By the former I mean, as before explained, the examination of thin sections after they have been enlarged by my potash-gelatine method, and viewed by the aid of a simple lens. In following the line of the callosal tract it is natural of course to begin with the origin of its fibres. Where are the callosal fibres derived from in the human brain? When the mezzoscopic and microscopic methods of examination are employed this can be clearly enough made out, and, as a general statement, it may be said that the area which supplies them extends mesially from the upper edge of the gyrus fornicatus round nearly to the free border of the operculum and its continuation backwards in the upper lip of the Sylvian fissure. Those from above curve inwards, while those from the outer convex surface run in an almost straight line to their point of entrance into the *tectorial part*. I have previously mentioned that, in the band in which the direct motor fibres coming down from the motor area to the inner capsule are contained, there is a certain number of fibres which turns inwards towards the corpus callosum. Anteriorly, this band, as before described, is almost exclusively composed of these, and they continue along the whole extent of the corpus callosum, but opposite the central convolutions other fibres which are evidently motor join it.

It is from the extreme vertex that the greatest leash of callosal fibres is derived. In man, the mass formed by them can readily be seen with the naked eye, and in Mammalia the number derived from here is proportionally larger than in man. They curve downwards and inwards, intermingle slightly with those callosal fibres which have already crossed, and are then lost in the tectorial part. Lying on their inner side is an immense mass of *association* fibres, apparently uniting the margin of the longitudinal fissure with the gyrus fornicatus, but those fibres which are to enter the corpus callosum soon show their bent by curving inwards. As the fibres which have crossed the corpus callosum turn downwards in the *crossed callosal tract*, and as the most of those which are about to enter it run almost in a straight line from the cortex inwards, it follows that an interlacing of the two sets must take place, and this is most beautifully seen in microscopic preparations made on a large scale. The two sets of callosal fibres are arranged in bundles, and these interlace in an almost inextricably dense plexus.

I doubt whether callosal fibres are derived from the extreme edge of the operculum. Two other sets of fibres undoubtedly arise from here. The one is an *association* band of large size, which unites the edge of the operculum to the island of Reil (Plate XXII. *g. g. g.*). The other (*f. f. f.*) runs into the outer capsule and constitutes its outer half; but whether, over and above these two sets of fibres, there are still others derived from the edge of the operculum which enter the corpus callosum, I cannot as yet define with precision, and am inclined to believe that there are not. A question also arises as regards the fibres of the gyrus fornicatus: Are its fibres callosal, or, if not, where do they go to? My belief is that they are chiefly of the *association* variety. A large longitudinal mass of fibres is seen running antero-posteriorly when the grey matter of the convolution is removed.

The callosal fibres being thus gathered in from this vast origin, let us trace their progress further onwards to the opposite side. When they enter the tectorial part of the corpus callosum, they are arranged in dense bundles which follow a more or less parallel course. In the middle line, however, this parallel arrangement ceases, and the bundles of fibres interlace as in the decussation

of the pyramids. The decussation can be seen perfectly well with the naked eye, or with a simple lens, in a mezzoscopic preparation, the bundles having a peculiar shining appearance when they are cut obliquely; not only do the bundles decussate, but they alter their direction. They appear all to lie very much in the same perpendicular plane when they enter the tectorial part, but as they issue at the other side, the bundles pursue more or less of an oblique course towards the centre of the brain. The point to which they all tend to converge is the knee of the inner capsule; and those callosal fibres which lie in front of this, after crossing the middle line slope backwards, while those which come from the posterior part of the brain slope forwards. It consequently happens that, while the bundles of fibres going into the corpus callosum can be traced for a considerable distance perfectly continuously, those issuing from it in the *crossed callosal tract*, as they converge forwards or backwards, are almost invariably cut off more or less obliquely. It is only nearly opposite the knee of the inner capsule that the fibres of the *crossed callosal tract* can be seen to form long continuous bands when a perfectly transverse perpendicular section of the hemisphere is being examined. Indeed, in the adult brain the complex of fibres is so intricate in the region of the *crossed callosal tract* that it is extremely difficult to see these obliquely cut bundles at all, even in a microscopic section. In the thick mass of brain tissue from which the sections are cut, however, the crossed callosal tract, as before mentioned, is beautifully demarcated because the segments of crossed fibres are in such large mass, but in a mezzoscopic or microscopic section they are much less evident, the reason being that they are not in such numbers. For long I could not explain this apparent anomaly until I employed Weigert's acid-fuchsin method of staining. This acid-fuchsin (No. 130 "S" of the Baden Aniline Manufactory), as is now well known, when employed in the manner recommended by Weigert,¹ has the property of staining nerve fibres, while the grey matter remains uncoloured, and when skilfully applied is an excellent reagent for the demonstration of certain tracts, such as the present. Ordinary fuchsin is not available for the purpose; it is this

¹ *Centralblatt*, 1882.

particular variety—an acid aniline dye—which alone has this property. It seems to take a much more powerful hold upon the nerve fibres than upon the grey matter, in the presence of a chrome-potash salt. Now, as I have found by repeated trials, it seems to have a particular affinity for these crossed callosal bundles, so that, of all the nerve fibres in the neighbourhood, they appear the most deeply stained. Whether their oblique course has something to do with it or not I cannot say, but certain it is, that when they are coloured by this reagent they stand out in a microscopic section much more distinctly than other fibres. It may be, simply, that the nerve fibres are more closely packed in them than in other systems, because I have also noticed that the dense bundles of the inner capsule stain with like intensity.

By the aid of this substance the continuity of the fibres in the *pars tectoria* with those in the *crossed callosal tract* can be clearly defined, although it must be remembered that in a perfectly transverse section the fibres which cross in the tectorial part are not all the same fibres as those found in the crossed callosal tract of the same section. As I have stated, they turn obliquely forwards or backwards according to their position after crossing, so that a great many of those fibres issuing from the side of the tectorial part of the callosal tract are cut across shortly after they have emerged. If, however, an *oblique perpendicular section* be examined, the direct continuity of the fibres becomes evident, but as a single callosal fibre, if dissected out from side to side, would have a very twisted course, it is necessary that the brain be cut in various directions, in order that each set of preparations may show a particular part of the tract.¹ As the bundles approach the two capsules they become closely packed together (Pl. XXII., *h. h.*), so that in an acid-fuchsin preparation this region always has a dark-red colour. They are then seen to divide into two sets over the lenticular nucleus. The larger of these enters into the inner capsule, while the

¹ I would specially recommend anyone wishing to see the continuity of the *pars tectoria* and the *crossed callosal tract*, to examine microscopically an *oblique section* of the sheep's brain in a solution of potash. The brain of this animal is of convenient size, and the potash has a wonderful power of differentiation. The fibres are seen to run without interruption from the *pars tectoria* into the two capsules.

smaller passes into the inner stratum of the outer capsule. Let us leave them here for an instant to consider briefly what is the condition of the callosal tract in the embryo, as this affords most potent confirmation of the direct continuity of the different parts of the callosal tract and the two capsules.

As I mentioned in the introduction, this paper is essentially a description of the callosal tract *in the adult*, and hence I do not intend to enter at length into the appearance presented by it in the embryo. For minuter particulars, I must refer the reader to my paper on the "Embryonic Corpus Callosum," in *Brain*, for July 1885. I simply wish to draw attention to the fact that in a four months' human embryo, the callosal system of fibres is practically the only one developed in the brain. The motor and other direct fibres from the cortex, as yet, are not laid down. There is, therefore, in the four months' (end of third to the fourth) human embryo the best means of studying the course and connections of the callosal tract, apart from the many other systems which intermingle with and complicate it in adult life. The cortex in such an embryo is well formed, although its cells are of an elementary character. From it, rudimentary fibres are noticed running inwards towards the corpus callosum, and from either side the *crossed callosal tract* is seen coming out as a ribbon-like band, which, after circumventing the ventricle, terminates below by dividing into the inner and outer capsules. The antero-posterior measurement of the cerebrum, as compared with the size of the basal ganglia, is less in the embryo of this age than in the full-grown brain, and hence the *crossed callosal tract*, after issuing from the tectorial part, does not run so obliquely towards the thalamus. Its fibres can be traced on this account quite continuously downwards as a definite system, and I have seen the same thing in the embryos of many Mammals, even with the naked eye. The two capsules at this age, that is to say, before any motor fibres have appeared, are perfectly defined. Their shape is such as is seen in the adult, the chief difference being, of course, that the fibres are very rudimentary in structure, and are non-medullated.

The Callosal Fibres from the Extreme Frontal Region.

Such being the disposition of the callosal fibres derived from the vertex and upper two-thirds of the cerebral cortex, the next question comes to be—What is the arrangement of the fibres issuing from the extreme frontal and occipital regions, and with what parts do they lie in relationship? I shall consider the course of those derived from the frontal tip first. The common idea is, of course, that the callosal fibres arising from one frontal tip run backwards, cross in the genu of the corpus callosum (forceps anterior), and again find their way to the frontal tip of the opposite side. The corpus callosum is simply the meeting point of fibres having an equivalent attachment on both sides. I believe that this is an entire misconception of the arrangement, but in order to explain what I mean it will be necessary to enter a little more into detail.

Suppose that a series of *mezzoscopic* perpendicular transverse sections from the frontal lobe be examined with a simple lens the medullary substance will be found, a little behind the tip, to have no definite arrangement into bundles, nor can any fibres be distinctly seen, because the greater number in running from before backwards are cut transversely or obliquely. At some distance further back, however, the sections of the oblique fibres are noticed becoming inclined towards the centre of the medullary substance. They are gathered in from all the neighbouring grey matter, and are evidently running backwards. The first real differentiation that takes place in the white matter is noticed about the anterior border of the third frontal convolution. Here the fibres coming from the anterior frontal region are concentrated in a somewhat *oval-shaped area*, more pointed below than above. I am sorry that circumstances will not allow of my giving a drawing of this, as its appearance and relationship to neighbouring parts would then be better understood. It measures about 28 mm. from above downwards, and 10 mm. from side to side. Into it fibres enter abundantly from above (first and second frontal convolutions), and below it terminates in a leash of fibres, which passes downwards and inwards to the gyrus rectus. Its boundary is fairly well defined in a *mezzoscopic* preparation, but the whole mass of

fibres is totally invisible in a fresh unprepared brain, or even in one which has merely been hardened, and is still opaque. Running obliquely across it from below upwards, and more or less transversely to the direction of the bulk of its fibres, are numbers of other nerve bundles. They are best seen posterior to where the oval-shaped area first appears, and always have an oblique inclination from below upwards. They are strictly confined to the oval-shaped area, and look as if they were cut across in curving into it from the inside to pass backwards at the outside. I have said that the above area has an oval shape. Occasionally, however, where the leash of fibres to the gyrus rectus is well developed, this queue-like appendage gives to it a pyriform character. It is somewhat difficult to know what to call this concentrated mass of fibres, but the name of *the common frontal tract* (*tractus communis frontalis*) may perhaps be sufficiently distinctive.

Opposite the anterior third of the third frontal convolution, this *common frontal tract* splits somewhat abruptly into three others, to which I have given the names of *tractus medius*, *internus*, and *externus* respectively. These will be best understood by reference to Plate XXI., where they are depicted as they are seen shortly after they have been formed. The locality in which they are most apparent is, as will be noticed from the drawing, nearly opposite the middle third of the third frontal convolution. This usually holds good, but there appear to be slight differences in different brains as regards their exact location. As a rule, however, if a section is made in a plane intersecting the middle third of the third frontal convolution, these three tracts will be brought into view—I mean, of course, when the preparation is manipulated by the gelatine-potash method. Otherwise, there is almost no indication of their presence.

The *tractus internus* (*t.i.*) is of large size, and is conspicuous in such a preparation by the coarseness and peculiar shining, or glistening, appearance of its fibres. It measures, at the point at which its boundaries are best defined, from its upper extremity to where the tail-like appendage comes off below, about 27 mm., and 12 mm. from side to side at its broadest part. Its bundles run somewhat obliquely from below upwards, and, in a progressive series of sections, it can be shown that some of them (about a half)

are continuous with the oblique bundles just described as running across the *common frontal tract* further forwards. They become fewer and fewer postero-anteriorly until only a trace of them is to be found intersecting the *common frontal tract*. Still more anteriorly they vanish, and then the *tractus internus* is seen to be entirely composed of fibres running backwards. These oblique fibres, therefore, simply run forwards from the *tractus internus* into the *common frontal tract* for some distance; they afterwards curve outwards and backwards, and their future course will be described presently.

The *tractus internus* is found to become more and more densely fibrous the further backwards its fibres are traced, and a change is also noticed in the direction of its bundles, for whereas they are more or less obliquely inclined anteriorly, they assume an almost transverse direction posteriorly. The tract also approaches nearer the grey matter covering the inner aspect of the brain, and finally pierces through it. It joins with a similar mass from the opposite side, and the two constitute the anterior extremity of the corpus callosum. This *tractus internus* contains two sets of fibres. One of these, forming about half its bulk, is derived from the *common frontal tract*, that is to say, from the tip of the frontal lobe of the *same* side, while the other has crossed in the corpus callosum, and after curving, as just described, obliquely forwards and outwards, alters its course, and, as we shall see, passes ultimately backwards into the two capsules. Its fibres have been derived from the *opposite* anterior frontal region.

The *tractus externus* (Plate XXI., *t. e.*) is a very well-defined ribbon-like band. It resembles Gratiolet's optic radiation band to the occipital lobe in shape and in the sharpness of its outline. It measures from 2 to 7 mm. in breadth, and 34 mm. from above downwards. It is more or less concave internally, but is sharply angular at its lower external border. Its fibres are arranged in fine bundles, their course being, generally speaking, antero-posterior. It receives a long leash of fibres from the gyrus rectus, similar to, but larger than, that which enters the *common frontal tract*. Its length, from the part where it separates from the *common frontal tract* anteriorly to the point where it terminates posteriorly, is about 22 mm. A most important matter

is the position occupied by it in relation to the neighbouring convolutions. It corresponds exactly with the aphasic centre, that is to say, with from about a third to a half of the posterior extremity of the third frontal convolution and a small portion of the lower extremity of the ascending frontal. It lies very close to the surface, the distance between the cortex of the third frontal convolution and its outer border being not more than from 2 to 4 mm. Its fibres are of two kinds. The greater mass of them is made up of the bundles of the *tractus internus* which have passed obliquely *through* the *common frontal tract* and turned backwards; but, in addition to these, there are also direct frontal fibres derived from the *common frontal tract* itself. There is even a third set, namely, that well-defined leash or bunch which comes upwards into it from the gyrus rectus. I cannot as yet define, however, where the last go to, and hence will not say much more about them. It is possible that they ultimately cross in the corpus callosum. The two main systems of fibres to be remembered in connection with this tract are the crossed and the uncrossed. The former arise from the opposite frontal tip, cross in the genu of the corpus callosum, run into the *tractus internus*, and pass obliquely forwards, outwards, and backwards into the *tractus externus*. Whether Meynert's anterior peduncle (vorderer Stiel) of the thalamus is composed of these crossed callosal fibres, or is simply part of the direct bundles from the frontal tip, I am not as yet in a position to decide. I have often thought that its fibres were callosal in their nature, and described them as such in my communication to the Royal Society (*loc. cit.*), but I will not commit myself to saying, as yet, that this is proven. Their attachment to the thalamus, posteriorly, increases the likelihood of their being callosal. The other system of fibres entering the *tractus externus* is derived from the frontal tip of the same side. The two systems become inextricably mixed in the tract, and hence it is almost impossible to distinguish their further distribution in the adult.

The *tractus externus* must not be mistaken for the internal capsule. It lies in front of this, and, in a fresh brain, is entirely hidden in the medulla underlying the oro-lingual centres. The inner capsule, it will be remembered, commences where the common head of the caudate and lenticular nuclei is split by it.

The tracts I am at present describing all lie in front of the basal ganglionic grey masses, and indeed in part anterior to the anterior horn of the lateral ventricle. This is clearly seen in horizontal sections where the different tracts are exposed in their antero-posterior course. The *tractus externus*, however, does not continue beyond the common head of the above-mentioned ganglia, for here it splits into two segments. The internal of these is the inner capsule, the external is the outer capsule. In its course backwards it curves slightly inwards, and when it splits, the outer capsule diverges externally, while the internal continues the line followed by it, that is to say, postero-internally towards the anterior extremity of the thalamus.

The *tractus medius (t.m.)* is much smaller than either the *tractus internus* or *externus*. It is somewhat curved, and is concave on the inner side, but if measured continuously from above downwards its length is from 30 to 35 mm. It is broadest at its upper extremity, while at its lower it becomes extremely attenuated, and the sharp end in which it terminates points towards, and lies in close contact with, the medulla of the gyrus rectus. It is composed of curved fibres more or less obliquely cut. They seem to curve outwards, backwards, and inwards around the anterior horn of the lateral ventricle, with the wall of which they lie in close apposition posteriorly. I have had considerable difficulty in making out what this tract is derived from. The conclusion I have come to, however, is that it is simply part of the crossed callosal system, namely, that part of it which lies closest to the ventricle. The tract ends posteriorly by joining the *tractus externus*, and continues to form the part of the extremely curved crossed callosal fibres which are always seen lying adjacent to the caudate nucleus (Plate XXII., *b.b.*).

In summing up the facts of this rather complicated region I would state that the same rule holds good for the callosal system here as further back, namely, that the fibres of one cortex do not pass over to the opposite cortex, but that, after crossing in the genu corporis callosi, they sweep round the anterior horn of the ventricle to turn backwards into the inner and outer capsules. As can be seen in any horizontal section, it is the horn of the lateral ventricle which is the hindrance to their gaining the inner capsule, and in order to circumvent this they are

tilted forwards before curving backwards. Did the capsules lie anterior to the horn of the ventricle, there would be no need for this course. It is because the inner capsule commences far behind this obstruction that the intricate arrangement just described is rendered necessary. The decussation noticeable in the genu corporis callosi is more complex than in any other part, apparently from the large size and difference in level of the various bundles, those entering it lowest seeming to pass out highest.

It is difficult to make out in the adult the curved course of the callosal fibres anteriorly, as I have detailed it. In the embryo of from three to four months, however, it becomes remarkably easy. As before mentioned, the callosal system of fibres is almost the only one in existence in the brain of a human foetus of this age; and hence, if what I have described as the course of the callosal fibres round the ventricle in the adult be true, it ought to be seen with precision where these are not intermixed with the direct, "the association," and the other systems of fibres of the adult. Such it will be found is actually the case. The fibres of the internal tract are seen in the human embryo of this age issuing from the corpus callosum; they then wind completely round the anterior horn of the ventricle in a horizontal plane; they circumvent it, and terminate in the capsules behind. The anterior crossed callosal system, in fact, is simply a continuation of that seen in the mid-cerebrum, as may be understood from that drawing of Foville's (pl. xv.) to which I have already referred. Here it will be noticed that the ridge L, which I have before said represents the *crossed callosal tract*, turns down anteriorly in a direction corresponding to the convex anterior aspect of the brain, and fades off posteriorly towards the occipital lobes. It thus happens that, in horizontal sections at particular levels, the crossed callosal fibres will lie almost all in one horizontal plane anteriorly, and, consequently, will present much the same aspect as they do in the mid-cerebrum when cut in a transverse perpendicular direction. What Foville has produced, in fact, by his method of dissection, is very much the system of callosal fibres which is revealed in the four months' foetus, and hence it can be readily seen from his figure how, in a horizontal section of the foetal brain, the *crossed callosal tract* will

be found winding round the *front* of the ventricle instead of over it as in perpendicular transverse sections.

It is a well-known clinical fact that a destructive lesion situated in the oro-lingual area may give rise to aphasia of different kinds. These are apparently caused by a lesion involving the same structures, and, as yet, it has been unexplained why this is so. Thus (1) the lips and tongue may be employed for various other purposes, although they are useless for the purposes of uttering articulate sounds. The mental faculties in such individuals are not impaired, but what is lost is the power necessary for co-ordinating the oro-lingual muscles for speech. The condition, in fact, is a true ataxia or *aphemia* as it is called. (2) Another form of speechlessness is that which is known as *amnesia*, where the powers of articulation may be perfect, but where the memory of words has vanished, and the person becomes like a child learning to speak. More or less *agraphia* usually accompanies it. (3) A third variety is where the first and second are combined.

It would be apart from the object of this paper to enter into the discussion of the pathology of aphasia in its different manifestations, but in passing I may point out a feasible explanation of the diversity of the phenomena following a destruction of the neighbourhood of Broca's convolution. There can be little doubt that the cortex of the posterior part of the third frontal convolution and that of the anterior part of the operculum are centres for the combined movements of the oro-lingual muscles, but that they have any psychical significance beyond this is questionable. Where the cortex alone in this neighbourhood is destroyed, one can easily see how a pure *aphemia* might result, that is to say, a purely co-ordinative defect. Suppose the lesion went deeper, however, and encroached upon the *tractus externus*, which immediately underlies these centres, it would follow that the greater number of the fibres from the opposite pre-frontal region, as well as many of those from that region on the same side, would be more or less implicated. One can readily see that, according to the extent of this implication, the greater would be the deterioration of those higher faculties, whose substrata by custom and experience it has been usual to locate in the first and second frontal convolutions. It seems out of keeping with what is known of the functions of the cortex to

suppose that the small mass of grey matter comprised in the oro-lingual centres could preside over so manifold and important intellectual functions; and I would merely suggest, as an explanation of this apparent anomaly, that this point of the brain surface is, of all others, that at which the fibres coming from the two pre-frontal regions could be most readily injured.

The Callosal Fibres from the Postero-parietal, and Occipital Regions.

The number of callosal fibres obtained from the postero-parietal, and occipital regions does not seem to be so great as from the frontal. Running through the occipital and parietal lobes posteriorly, there are two bands, as seen on perpendicular transverse section, representing two different systems. The one is the occipital part of what Gratiolet named the "optic radiations." It stretches from the occipital tip to the posterior part of the inner capsule, and a large offshoot from it runs forwards as far as the island of Reil. With this system of fibres we are not concerned at present. The other system is callosal, and its fibres seem to sweep in from the neighbouring convolutions, and to pass through the "optic radiation" band in bundles. They subsequently become concentrated in a dense layer in the wall of the posterior cornu of the lateral ventricle, constituting what is known as the *tapetum*. At first they are most abundant on the external wall, but as the splenium corporis callosi is approached, they twist round the ventricle above and below, and issue through the grey matter on the inner aspect of the hemisphere in a dense mass similar to that seen in the formation of the genu anteriorly. They then seem to cross in the splenium, and pass thence into the posterior limb of the inner capsule. The fibres of the "optic radiation" band are gathered in from the parieto-occipital region also, but they appear to be more numerous than those which are callosal. The two sets of fibres, however, seem to lie side by side at their origin, and are quite indistinguishable.

Destinations of the Callosal Fibres.

Having thus traced the callosal fibres from their origin in the cortex down to the capsules, in the middle, anterior, and posterior

cerebral regions, the problem remains to be solved as to where they go to after entering the capsules.

It can be easily seen that they tend to converge towards the thalamus, and it is undoubtedly within this ganglion that a great many of them terminate. We constantly hear the term "knee of the inner capsule" employed to designate the dense mass of fibres which lies at the point of union of its anterior and posterior limbs, but, so far as my own inquiries go, no explanation of the meaning of this aggregation of fibres has ever been given. It might be supposed that the fibres of the anterior and posterior limbs met here before descending to the pedunculus cerebri. The fibres of the pedunculus, however, do *not* descend at this point, but at a considerable distance behind it. It is utterly untenable to suppose that the whole mass of the inner capsule fibres passes into the pedunculus. The knee of the inner capsule is certainly a point of junction, yet the fibres comprising it do not all descend, but the majority of them become attached to the adjacent thalamus. The direct motor fibres descend, and the callosal at this point become lost in great part in the grey matter of the thalamus. The *knee* of the inner capsule, in fact, is not inner capsule at all, but a segment of the grey matter of the thalamus beset with a vast complex of fibres. In Plate XXII. the anterior border of the *knee* is alone represented, but it will be noticed that even here the inner capsule has already lost the bulk of its fibres by their leaving it to become bound up with this ganglion. It is only at a point posterior to the *knee* that its bulk again increases, from the fact that its fibres are recruited by those coming from behind. I think that not the whole, but *nearly* the whole, of the crossed callosal fibres in the anterior limb of the capsule end here or in some other part of the thalamus.

Some of them seem to enter the caudate nucleus, but only a very few. It is a curious fact that the caudate nucleus in *Man* appears to receive very few terminal fibres. The majority of the bundles seen in it appear to pass completely through, and do not form a permanent attachment to, its cells. As to whether the lenticular nucleus receives any of these crossed callosal fibres I cannot with certainty indicate. I have not as yet investigated this point with that care which it would require for its elucida-

tion. Numerous fibres go from the inner capsule to the lenticular nucleus, but whether these have come from below or from above is by no means easy to settle. If they come from above there then follows the query whether they are crossed callosal or direct descending. I will not, in the face of insufficient evidence, hazard any opinion on the subject, which might be misleading. I think, however, that it is very likely that the *striae medullares* at least of the lenticular nucleus may be crossed callosal. This seems probable from their origin above, and from the course of their fibres through the nucleus corresponding closely with that of the fibres of the outer capsule.

Now the descending fibres of the *pedunculus cerebri*, as they become visible on the base of the brain, and afterwards, are far more abundant than the attenuated tracts of the anterior pyramids, and hence it follows that many of them must lose themselves and become attached within the pons. I think that it is very likely that many of these peduncular fibres are crossed callosal, and that they become united with the large masses of grey matter intercalated between the transverse fibres of the pons. It might also be conjectured, although this is a mere conjecture, that some of them may similarly be in communication with the ganglia of the medulla oblongata or with nerve cells of its reticular tissue. Whether the *segmental corona* becomes ultimately callosal or not, I cannot as yet say.

It will be seen that I do not regard the ordinary *peduncular corona radiata* as existing in the form that is generally described. The only fibres of the cerebral peduncle which radiate out into the hemispheres of the same side are the direct motor fibres, along with those special bands going to the occipital lobe and to other definite situations. These, however, constitute but a small portion of the inner capsule. The great mass of the fibres which apparently radiate outwards from the inner capsule to the cortex of the same side, in reality crosses in the corpus callosum to the opposite side.

Is, then, the entire centrum ovale constituted by these two sets of fibres—the crossed and the direct? It certainly is not, for it requires a very superficial examination to discover that the “association system,” or that class of fibres which runs between the different convolutions, constitutes a by no means

small complement of the medullary white matter. In large microscopic preparations, enormous bands, which seem at first to be running downwards from the cortex towards the inner capsule, are found, if traced sufficiently far, to sweep round to a neighbouring convolution. As this system, however, does not concern us at present, I shall dismiss its consideration, and merely remark, that the white matter of the cerebrum appears to be *mainly* constituted of three great systems. The first is the *direct*, which comprises such fibres as the motor from the neighbourhood of the fissure of Rolando, the direct so-called *sensitive* band from the parieto-occipital region, the anterior peduncle of the thalamus, &c. The second is the *crossed callosal*, with the origin and connections described; and the third is the association class of fibres running between different convolutions.

It has been briefly stated in the first part of this paper that the *crossed callosal tract* also ends partly in the *outer capsule*; and I now wish to direct more particular attention to what becomes of the fibres entering this body. The outer capsule, as can be readily seen from such a drawing as that of Plate XXII., consists of two layers. The external (*fff*) takes origin from the margin of the operculum and edge of the Sylvian fissure posterior to this; whereas it can be distinctly noticed that the internal is an offshoot of the *crossed callosal tract*. It would require a special treatise to describe the terminations of these crossed callosal fibres entering the outer capsule, for I believe that it is one of the most important structures in the human brain. Briefly speaking, however, I may say, without entering into particulars, that it terminates below in the following parts:— (1) Most anteriorly a leash of fibres comes off from it which below enters the inner capsule, mingling with the bundles of this structure, and losing itself among them. (2) The next offshoot is to the olfactory tract—a very large bundle which, so far as I know, has never been described. A few of these fibres are seen in Plate XXII., at *a.c.o.*, but the plane of section is too far back to show them properly. The bundle is large, and seems to be one of the chief origins of the olfactory. (3) The third offshoot is to the anterior commissure. (4) The fourth, a most important one, is to the optic tract.¹ When I say that in man

¹ See my communication on this subject, *Proc. Roy. Soc. London*, April 17, 1884.

the optic tract is largely derived from the outer capsule, I am afraid the statement will be discredited by most anatomists. It is, however, I believe, perfectly true that a great mass of fibres enters the tract from this source, and these again seem to be crossed callosal. (5) The fifth and last connection of the crossed callosal fibres of the outer capsule is with the temporo-sphenoidal lobe,—a connection very readily seen, but not usually described.

In conclusion, it may be asked—Granted that the majority of the callosal fibres have the origin and destinations I have described, is it not possible that *some* of them may be commissural? I shall not venture to deny what cannot be positively disproved, but would say in reply, that if there are any such, they must be in small number, because the *crossed callosal tracts*, taken together, more than correspond to the bulk of the tectorial part of the corpus callosum. For my own part, I do not believe that they exist.

It would be idle to speculate, at the end of a paper such as the present, upon the functions discharged by these various connections of the corpus callosum in the brain of man and the higher mammals. It is not speculation but undeniable evidence which is required in a subject such as this; and, as I said in the commencement that this paper was essentially to be a description of the origin and destination of the callosal system in the adult, I must leave this other most important aspect of the question untouched for the present. I frame no theories upon what I have described. I have merely related what I have seen; and if, from the want of illustration, the reader may not have derived the same vivid impressions as the data have conveyed to my own mind, I trust that at some future time this defect may be remedied under more favourable auspices.

EXPLANATION OF PLATES XXI, XXII.

PLATE XXI.

Perpendicular transverse section through the adult human brain, a short way in front of the genu corporis callosi. 1 *Fr. C.*, first frontal convolution; 2 *Fr. C.*, second frontal convolution (above and below); 3 *Fr. C.*, third frontal convolution; *G. R.*, gyrus rectus; *G. f.*, gyrus fornicatus; *t. i.*, tractus internus; *t. m.*, tractus medius; *t. e.*, tractus externus; *a. a.*, band of fibres from gyrus rectus to tractus internus; *b. b.*, band of fibres from gyrus rectus to tractus externus; *c. c. c.*, callosal fibres entering the tractus internus from the 1st and 2nd frontal convolutions; *d. d. d.*, association system of fibres.

PLATE XXII.

Perpendicular transverse section through the adult human brain in the region of the anterior commissure. *As. Fr.*, ascending frontal convolution; *As. Pr.*, ascending parietal convolution; *T. S. L.*, temporo-sphenoidal lobe; *G. f.*, gyrus fornicatus; *C. C.*, corpus callosum; *L. V.*, lateral ventricle; *III. V.*, third ventricle; *f. M.*, foramen of Monro; *Fx.*, arch of the fornix; *Fx. p.*, the anterior pillar of the fornix coming backwards; *A. C.*, anterior commissure; *ol. A. C.*, olfactory fibres from the anterior commissure; *ol. s.*, olfactory sulcus; *Th.*, thalamus—anterior tubercle; *I. C.*, inner capsule; *S. m.*, stria medullaris; *L. N.*, internal segment of lenticular nucleus; *L. N.*, external segment of lenticular nucleus; *O. C.*, outer capsule; *Cl.*, claustrum; *w. s. I.*, white substance of island of Reil; *I. R.*, island of Reil; *C. N.*, caudate nucleus; *a. a.*, fibres of inner capsule entering the thalamus; *b. b.*, fibres of inner capsule entering the caudate nucleus; *o. c. o.*, fibres of outer capsule to the olfactory; *d. d. d.*, uncrossed fibres entering the corpus callosum; *c. c. c.*, crossed callosal fibres or "the crossed callosal tract;" *f. f. f.*, fibres of outer capsule to the operculum; *g. g.*, association system, band from edge of operculum to island of Reil; *x. x. x.*, junction between gyrus fornicatus and tectorial part of corpus callosum; *h. h.*, short obliquely cut bundles of crossed callosal tract as they enter the inner capsule.

TUMOURS IN ANIMALS. By J. BLAND SUTTON, F.R.C.S.,
*Lecturer on Comparative Anatomy and Senior Demonstrator
of Anatomy, Middlesex Hospital Medical College. (PLATE
XXIII.)*

THE question of tumours in animals has never been adequately considered, consequently nothing definite is known concerning them. Domestic animals are very liable to be affected with morbid growths, and as such beasts as horses, asses, oxen, sheep, goats, pigs, dogs, &c., are often of considerable value to their owners, their diseases have attracted attention. This has had the good effect of causing a large number of tumours occurring in them to be placed on record. With only one exception, that of melanotic sarcoma, they have never been systematically described. In the present article it is proposed to discuss the comparative pathology of tumours, making cautious use of recorded cases, and to add numerous instances coming under my own observation. Throughout I shall endeavour to limit myself to simple statements of facts, avoiding theory as far as possible.

The term "tumour" will be used in a very definite sense, in order to exclude hyperplasias, and the infective granulomata, such as glanders, tubercle, actinomycosis, and the like :—

A tumour is a new growth, characterised by histological diversity from the matrix in which it grows; it is distinguished from inflammatory new-formations by the variety of its forms, mode of origin, and the frequent inherent tendency it has to increase.

Tumours, though more prone to occur at certain spots than at others, may be met with in any organ or tissue of the body. Among animals the commonest places for tumours are the bones, anus, mammary glands, orbits, mouth, abdominal lymphatic glands, and subcutaneous tissues in all regions of the body. As in man, certain forms of tumours exhibit a great tendency to reproduce themselves in distant organs, and to recur after removal; such are termed *malignant*. The commonest situations for these secondary or metastatic deposits, as they are frequently called, are the liver, spleen, lungs, and abdominal lymphatic glands.

Other tumours never show this malignant tendency, only becoming dangerous by their bulk or situation interfering with the functions of important organs. This latter group are usually separated by a layer of neutral tissue from the surrounding structures, hence they are said to be *encapsuled*. If they grow from the walls of a cavity, or near one of the natural openings of the body, such a tumour has a tendency to become stalked or pedunculated; it is then termed a *polypus*. Many of the malignant growths diffuse themselves through the organ or tissue in which they originate, and lacking a definite capsule are said to be *infiltrating*.

The following facts apply to all tumours. They are, for the most part, solitary, but may be multiple. They are very liable to retrogressive changes—fatty, mucoid, calcareous, or pigmentary. Hence they may soften, liquefy, and form spurious cysts. They often ulcerate, and if their nutrition is interfered with, suffer necrosis. There is no limit to their growth, so that under favourable conditions they may attain to very considerable dimensions. Morbid growths exhibit a strong tendency to attack functionless or abnormal organs. If the growth disseminates itself, this may take place in two ways, either by the blood-vessels or by the lymphatics.

Tumours, even the most malignant, transplanted into healthy tissues fail to grow,¹ and we have little reliable evidence as to their capability of inoculation.

CLASSIFICATION.

The most scientific basis on which to found a classification of tumours is undoubtedly an embryological one, leaving the histological details to determine the varieties. In this way tumours are divided into two great classes—those arising in tissues mesoblastic in origin, and those found in tissues formed from the epiblast and hypoblast. This arrangement is by far the most satisfactory that has as yet been proposed, and will be strictly adhered to throughout this article.

It will perhaps be convenient to briefly summarise the more important organs derived from each of the three germinal layers.

¹ *Vide* Melanotic Sarcoma, page 454.

1. *Epiblast*.—This layer gives rise to the central nervous system and the epidermis; the dermis is of mesoblastic origin (so that the line of junction between the epiblast and mesoblast is indicated by that between dermis and epidermis) the tegumentary organs and the lens. The peripheral and sympathetic nervous systems. The retina, including the pigmented layer. The epithelial expansions of the membranous labyrinth, and the lining membrane of the nasal fossæ. The cavity of the mouth and anus, including the glands peculiar to these cavities and the pituitary body.

2. *Hypoblast*.—From this layer the epithelium of the digestive canal, trachea, bronchia, and air cells is derived. The epithelium of the ducts of the liver, the pancreas, thyroid body, the other glands of the alimentary canal, and the hepatic cells. The lining of the allantois is of hypoblastic origin, and probably the notochord.

3. *Mesoblast*.—The muscles, the bones, connective tissues, and vessels, including arteries, veins, capillaries, lymphatics, and their lining epithelium, are derived from this layer. The generative and urinary organs also come from this layer. It must be borne in mind that the connective tissue, vascular and muscular elements of epiblastic and hypoblastic structures, are derived from the mesoblast.

The following table gives the arrangement of tumours according to the embryological plan. Each group will be dealt with separately according to the order in the table. The subdivisions will be made when each group is separately considered :—

Mesoblastic Tumours.

1. Fibromata.	7. Angiomata.
2. Myxomata.	8. Lymphomata.
3. Lipomata.	9. Myomata.
4. Enchondromata.	10. Neuromata.
5. Osteomata.	11. Sarcomata.
6. Odontomata.	

Epiblastic and Hypoblastic Tumours.

1. Adenomata.	2. Carcinomata.	3. Papillomata.
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Teratoid Tumours.

These contain tissues arising from the three layers.

MESOBLASTIC TUMOURS.

FIBROMATA.—Fibromata are tumours which agree in structural details with fibrous tissue. In consistence they vary much, in some instances being hard, dense, and creaking under the knife, at other times they are soft and present a greyish translucency. The softer forms of fibromata are rich in cells, spindle-shaped or caudate. The tougher examples are made up of bundles of wavy

fibrous tissue, presenting a peculiar whorled appearance containing few cells. In man these tumours may occur in any organ or structure which contains connective tissue. In animals the most common situation is the subcutaneous connective and sub-mucous tissue.

The museum of the Royal College of Surgeons contains several specimens of this nature removed from animals. The following cases are selected from the catalogue :—

The first specimen is a cluster of tumours, mostly globular in form, varying in size from half an inch to 3 inches in diameter, growing in or beneath the mucous membrane of the stomach of an ox, and projecting into its cavity. On section they present an uniform greyish-white colour, with numerous paler, wavy, fibrous bands intersecting each other, like those seen in fibro-myomata of the uterus.

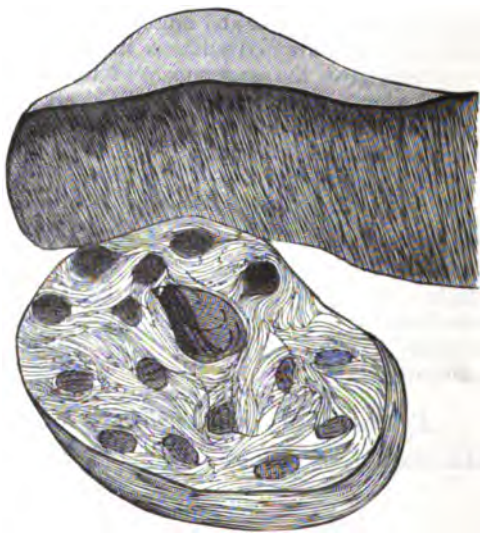


FIG. 1.—A fibrous tumour attached to the stomach of a Cod-fish (reduced to one-fifth its actual size).

The second case was taken from a cod-fish. It lay in the loose tissue beneath the skin in the abdominal region. This growth presents an interesting feature, for it had undergone calcification, thus showing that in animals secondary changes take place, as in similar tumours occurring in man.

The third case represents a tumour taken from the stomach of a cod-fish, where it had apparently originated in the submucous areolar tissue. Its section shows a homogeneous basis of a pale grey colour,

intersected in various directions by curving bundles of white, glistening fibrous tissue.

The fourth case is also from the stomach of a cod-fish. It is of oval form, and measures 9 inches in the major and 5 inches in the minor axis. It appears to have grown between the coats of the stomach. In structure it corresponds with the growths previously described (fig. 1). The museum contains a fifth example, springing from the psalterium of the stomach of an ox. It is deeply lobulated and of considerable size, being attached by a small pedicle. The tumour is composed of reticulated fibrous tissue.

The fifth tumour occurred in a variegated rat; the entire animal is preserved in the museum. Lying immediately beneath the skin of the neck and entirely confined to the cellular tissue, is an enormous tumour relative to the size of the animal. It measures 3 inches in its longest diameter. Histologically it is composed of coarse fibrous tissue (Plate XXIII. fig. 1). Virchow¹ figures an interesting example of fibrous pedunculated tumours attached in great number to the interior of the gall-bladder of a cow, giving it a villous aspect. Horses are liable to fibromata, especially in the neighbourhood of the scapulæ.

It must be borne in mind that all fibrous tumours may not have been composed of fibrous tissue originally, but may have consisted in great part of unstriped muscle fibres, which has later degenerated into fibrous tissue. The tumours of the stomach of the ox and cod-fish appear to be of this nature; the tumour of the rat is a genuine fibroma. It has long been recognised that muscles little used or paralysed do after a time become wholly represented by a mass of fibrous tissue, and the same change certainly affects the non-striated variety of muscle fibre.

The following case, recently described by M. Cadéac in the *Recueil de Médecine Vétérinaire*, March 15, 1885, seems to support my view concerning the fibroid tumours attached to the alimentary canal. A tumour, about the size of a child's head, was found on the duodenum of a mare, which had died from rupture of the stomach, caused by the growth. The tumour was hard, resistant, of a greyish-white colour, and enveloped the stomach like a muff, and so narrowed the lumen of the gut, that it only measured 2½ centimetres at this spot. Histologically examined, the growth was found to be a fibro-myoma composed of undulating wavy fasciculi, each fasciculus containing fusiform cells with a distinct and elongated nucleus. In parts the tumour showed areas of fatty degeneration.

Melanotic Fibromata.—Cornil and Trasbot² describe under this name a very rare form of tumour, which occurs in horses. They have observed three examples of it. The growths are black or of a sepia colour, and seem to arise from hyperplasia of the con-

¹ *Pathologie des Tumeurs*, tom. i. p. 337. (French edit.)

² *De la Mélanose*, 1868.

nective tissue, accompanied with a deposit of pigment in the meshes.

They are always primary tumours, generally of small volume, spheroidal or hemispherical in shape, and there is never more than one on the same animal. In two of the patients the growths were at the base of the tail or around the anus, equal in size to a man's fist. One case, however, occurred in the flank. All three of the tumours arose in the subcutaneous connective tissue. Histologically, the tumours presented the characters of fibrous tissue infiltrated with pigment granules; in no part of the growth was it possible to detect sarcomatous elements. The melanotic fibromata grow slowly, and if removed do not return. The third case, an old mare, set aside on account of age, was allowed to live some time after the tumour was discovered. Eventually she was dissected in every part, but no secondary deposits could be detected.

M. Cadéac¹ has recently described an example of this rare growth in a cow aged seven years. It was situated in the middle of the buttock, superficially, and was of small size. He makes reference to two other cases also in cows.

MYXOMATA.—Up to the present time I have been unable to find any recorded case of a myxomatous tumour occurring in animals other than man. No example has come under my notice.

LIPOMATA.—Fatty tumours occur occasionally in domesticated, but are excessively rare in wild animals; even those born in captivity form no exception to the rule.

As in man, they usually arise from normal adipose tissue; yet the occurrence of fatty tumours in the connective tissues of certain regions of the body, which normally contain no fat, is not unknown. Histologically such growths conform to the structure of adipose tissue; if the tumour be large it is usually made up of fatty tubules bound together by fibrous septa.

These growths are rarely the seat of secondary changes; the most important perhaps is the deposit of earthy matter (calcification).

It is not uncommon in oxen and horses to find fatty tumours

¹ *Recueil de Méd-Vétérinaire*, March 15, 1885.

sometimes of considerable size, hanging pendulous from the intestines. There is every reason to regard them as hypertrophied appendices epiploicæ. A typical specimen is represented in fig. 2, taken from the museum of the Royal College of Surgeons, London.



FIG. 2.—A fatty tumour hanging pendulous from the intestine of an Ox (one-third the natural size).

It was attached by a long narrow pedicle to the exterior of the intestine of an ox. It is composed of two chief parts united by a narrow isthmus, and each is of an elongated oval form. It is about 6 inches in length and 2 inches in diameter. The fat of which it is composed is firm, like beef-suet, and lobulated.

It is interesting to note that in most of these specimens the pedicle is narrow, this being probably produced by the constant swinging of the tumour from the bowel. In some cases the pedicle becomes so thin that the tumour breaks loose and falls into the peritoneal cavity.

On one occasion two fatty tumours, which had become detached in this way, were found in the peritoneal cavity of a mare. The larger one measured 4 inches by 3, the lesser 3 inches by 2½. They were completely invested by serous

membrane, and on section presented the granular appearance characteristic of omental fat. The point of attachment of the pedicle could not be determined for certain. These specimens are now in the museum of the Middlesex Hospital. Pedunculated tumours of this kind are often a source of danger to the animal, as they are apt to lead to strangulation of the bowel. The *Veterinarian* (vol. viii., 1862) contains numerous cases illustrating this fact. The following instances will serve as examples:—

A horse, thirty-three years of age, was attacked with violent spasmodic colic, which ended fatally. The strangulation was found to be caused by a pedunculated fatty tumour, the size of a cricket ball, attached to the small intestines. The pedicle had encircled the gut and strangulated it.

In the second case a horse died with all the symptoms of strangulation of the bowel. At the *post-mortem* examination two pedunculated fatty tumours were found swinging from the mesentery near to the attached border of the bowel, directly opposite each other. One of the tumours had by its weight torn through the mesentery and encircled the small intestine leading to fatal strangulation.

A fatty tumour, weighing two pounds, has been found attached to the duodenum of a horse, in whom it was the cause of invagination of the bowel.

Lipomata attached to the bowel are not unknown in man. Virchow, in his great work on tumours, figures an undoubted example of pendulent fatty tumours hanging from the colon in man, and draws attention to the fact that the narrow pedicle of these tumours easily undergoes torsion, leading to defective nutrition of the mass, and secondary changes such as cretification. Later, these masses, large or small, may become detached, and then, as loose bodies, occupy the peritoneal cavity, often giving rise to curiosity at the autopsy as to their probable origin, as well as on account of the hardness and singular shapes some of them assume.

All loose bodies in the peritoneum do not arise in this manner, some must be regarded as calcified subserous uterine fibro-myomata which have broken their pedicles.

Lipomata occurring in such situations as those last described are easily explained; but a fatty tumour in the substance of the heart is not so comprehensible. A remarkable case of this kind may be found in the museum of the Royal College of Surgeons; it is thus described in the catalogue:—

The heart of a sheep greatly enlarged by the growth of fat on its exterior and in its cavity. The muscular walls of the auricles and ventricles are very thin. The cavity of the right ventricle is nearly filled by a lobulated mass of suet-like fat, which has distended the walls and pressed back the tricuspid valve so as nearly to close the orifice into the auricle. The lining membrane of the ventricle and the pulmonary artery are healthy. The cavity of the left auricle is encroached upon by a large mass of fat projecting into its interior, and the lower half of the left ventricle is occupied by a tumour of the same kind as that in the right ventricle. The valves and the aorta are healthy. The heart weighed two pounds three ounces, the weight of the fat added to it is therefore about twenty-five ounces. The sheep from which it was taken was very inactive and had dyspnoea on exertion. There was a great accumulation of fat around the kidneys.

The mass of fat lying anterior to the testes or ovaries, in the male and female frogs and toads respectively, known to anatomists as the "corpus adiposum" is an interesting structure. The researches of embryologists prove most conclusively that the fat-body is really the degenerated remains of the anterior portion of the genital ridge of the embryo, the mass of cells from the posterior part of which the ovary or testis is developed. Thus every frog born into this world normally inherits a "fatty tumour" in connection with its reproductive gland. Occasionally it happens that this fatty degeneration does not limit itself to the anterior portion of the genital ridge, but may involve the testicles also.

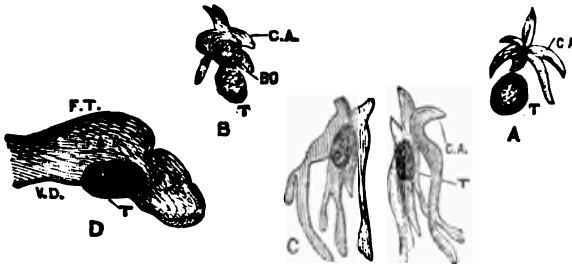


FIG. 3.—(A.) The testis, T, and corpus adiposum, C.A., of a Frog (*Rana temporaria*). (B.) The testis, T, corpus adiposum, C.A., and Bidder's organ (remnant of ovary) of a Toad (*Bufo vulgaris*). (C.) Abnormal corpus adiposum, involving testis, of a young Frog (*Rana temporaria*). (D.) Malformation of reproductive organs of a Monkey. T., testis; V.D., vas deferens; F.T., Fallopian tube. Fat replacing the ovary. The uterus was of the usual shape, but the vagina small, with a narrow orifice.

The accompanying figures (fig. 3) represent the corpus adiposum of a frog (A), of a toad (B), and an abnormal one (C), involving the testis.

In an example of malformation of the reproductive organs which occurred in a monkey (*Cercopithecus lalandii*), in which case there was a uterus and vagina, associated with testes, a large mass of fat exactly recalling a corpus adiposum of the frog lay above each testis. It may be argued that, strictly speaking, these should rather be considered as degenerations; but as they increase in size, and are foreign to the matrix in which they are situated, strictly they fall in the ranks of tumours.

Those masses of fat, usually called fatty tumours, which occur in the subcutaneous tissue, have no claim to be designated as such, but ought to be regarded rather as examples of local hypertrophy. The term lipomata being reserved for those tumours composed of fat, which grow in such situations as the palm of the hand, in the substance of the tongue, in relation with striped muscle, or in the substance of the heart, as in the case of the sheep just detailed. It is only in such situations as these that we can truly say that the tumour presents *histological diversity* from the matrix in which it is situated.

ENCHONDROMATA.—This term is applied to tumours which consist essentially of cartilage. The fact that these growths may be pervaded by tracts of fibrous tissue for the conveyance of blood-vessels to nourish the abnormal mass, does not at all affect the definition. Some pathologists propose to limit the term enchondromata to tumours which do not arise from pre-existing cartilage, and propose to call those growths which arise as a local overgrowth of cartilage—*ecchondroses*. This limitation of the term will not hold good, for there is abundant good evidence to support Virchow's view regarding the probability that many osseous enchondromata originate in remnants of cartilage, which have abnormally remained unossified. This will be referred to in dealing with the ætiology of tumours.

The following instances of cartilage tumours have come under my notice:—

A Lizard (an Indian Monitor), which was extensively affected with rickets, presented numerous enchondromata in various parts of its body. The two largest were found at the fifth and seventh cervical vertebræ, and considerably expanded their centra. A large mass surrounded the glenoid cavity of each scapula. The right humerus presented two large growths imme-

diately above the condyles (fig. 4). The left humerus presented one. The metacarpal bones possessed two, near their distal extremities; and four were found growing on the cornua of the hyoid bone. Histologically these growths were composed of hyaline cartilage.

A bird (a young Rhea) died in consequence of a fractured leg. Its

skeleton was affected throughout with rickets, but on each metatarsal bone an enchondroma, the size of a walnut, existed. The metatarsus of bird

is confluent; that is to say, the three bones forming that segment of the pes are fused so as to form a single bone. At the proximal end, in young birds, an epiphysis may be detected. This epiphysis really represents the distal row of tarsal bones seen in mammals, but in birds it fuses with the metatarsus. A line of cartilage exists between the two parts in all young birds. In the case under consideration the tumour clearly originated as an overgrowth of this epiphysial cartilage, and agreed with it in structural details (*vide* fig. 5).

Among curious situations for enchondromatous tumours to occur must be mentioned the lungs, mammary gland, and the testicle.

The growth in one well reported case¹ was found in the lung of an ass. It occupied the dorsal surface of the left lung posterior to the root. The tumour weighed eighty-four drachms, and measured 7 inches in length, 8 inches in width, and 3 inches in thickness. It was microscopically examined by

¹ *Veterinarian*, 1851.



FIG. 5.—Metatarsal of a Bird (*Rhea americana*), with a cartilage tumour in connection with its epiphysis (*Path. Soc. Trans.*, vol. xxxiv.).

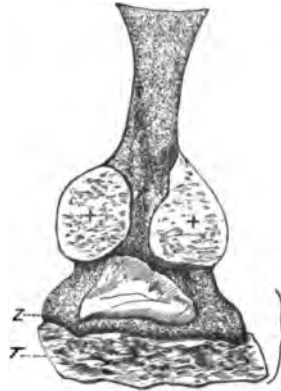


FIG. 4.—Humerus of a Monitor Lizard, with enchondromata (*Path. Soc. Trans.*, vol. xxxiv.).

composed of a large quantity of fibrous tissue, which formed a dense interlacement throughout the tumour. Cells, resembling cartilage cells, were found with an amorphous intercellular material. In the softer portions of the tumour the cells were fewer in number, and the intercellular material contained numerous molecules and granules. In these parts the consistence of the tumour was softer than any variety of cartilage. Calcareous particles were diffused throughout the growth.

A tumour of similar character has been reported,¹ growing in the mammary gland of a bitch. Similar tumours have been found in connection with the testicles of colts.² In one instance a cartilaginous tumour, removed from this situation, was found to contain a calcareous mass as large as a hen's egg. Since Mr Butlin³ has investigated the question of the very frequent occurrence of masses of cartilages in spindle-celled sarcomata occurring in man, it seems exceedingly probable that these instances are to be regarded as chondrifying sarcomata and not primary enchondromata. This subject will be more fully dealt with when spindle-celled sarcomata are considered.

OSTEOMATA.—The osteomata are tumours composed of osseous tissue; they may occur in any part of the body, but their usual seat is in connection with the bones. It is usual to include all kinds of osseous formations under this term, irrespective of their origin. In some of the best museums in London, specimens are often described as exostoses, which are palpably of inflammatory origin. In this section the diffuse bony overgrowths known as Hyperostoses, those of less extent known as Osteophytes, and the Heteroplastic deposits, which may arise in tumours, in brain membranes, diaphragm, muscles, and in the choroid tunic of the eye, will be excluded.

Bony tumours, strictly speaking, are those circumscribed growths of non-inflammatory origin generally recognised under the term *Exostosis*, and similar masses occurring in the interior of bones known as *Enostoses*. Exostoses are by far the most widely diffused throughout the animal kingdom of any morbid growths.

As far as I can learn, William Bell was the first to describe the very curious exostosed condition of the bones of *Chaetodon*. The original description is in the *Phil. Trans.*, 1793.

The fish in question is generally about 18 inches long, 13 inches broad, and about 3 in thickness. It is frequently caught at Bencoolen and several other parts on the west coasts of Sumatra.

¹ *Veterinarian*, 4th series, vol. xvii.

² *Ibid.*, 4th series, vol. xxviii.

³ *Sarcoma and Carcinoma*, London, 1882.

"The skeleton is very singular, many of the bones having tumours, which, in the first fish Mr Bell saw, he supposed to be exostoses arising from disease; but, on dissecting a second, found the corresponding bones had exactly similar tumours, and the fishermen informed him they were always found on this fish; he therefore concludes them to be natural to it (fig. 6).

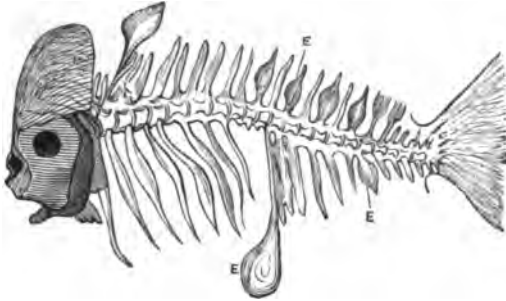


FIG. 6.—Exostoses on Chætodon (modified from Bell).

"In Mr Hunter's collection are two or three of these bones, but Mr Bell never knew what fish they belonged to; they were supposed to be from the back of some of the large rays.

"In Chætodon the tumours are spongy, and so soft as easily to be cut with a knife; they were filled with oil."

Bell's original specimen is in the museum of the College of Surgeons, with several other examples of this curious condition.

Rayer, in his *Archives de Méd. Comparée*, 1843, refers to Bell's observations, and mentions that the fish is called *Platax noduleux* by Cuvier, but that Schneider, in consequence of the exostoses, called the fish *Chætodon arthriticus (arthritique ou goutteux)*. Rayer further states that the collection of the Museum d'Histoire Naturelle contains some specimens of the exostoses, but they were extremely hard. On section the original limit of the ray could be detected in the thickness of the tumour. M. Valenciennes has also detected numerous exostoses on various parts of the skeleton of *Ephippus gigas*, which in common with other species of Squamipennes are liable to these tumours.

In *Ephippus faber* they affect particularly the occipital crest.

For my own part, I do not think, notwithstanding the fact that these exostoses are so frequent, they should be considered in any other light than that they are pathological.

Paul Gervais¹ has also recorded some admirable examples met with in fish. In fig. 7 the anterior vertebræ and corresponding dorsal rays of a Scabbard fish (*Lepidopus*) are represented of the natural size. Four of the dorsal rays bear an exostoses on their under surface.

In another fish (*Pagrus unicolor*) obtained from Australia, a large exostosis was found to have developed on the occipital crest. It is

¹ *Journal de Zoologie*, vol. iv. 1875.

represented two-thirds its natural size in fig. 8. A similar, but much smaller, growth lay posterior to it.

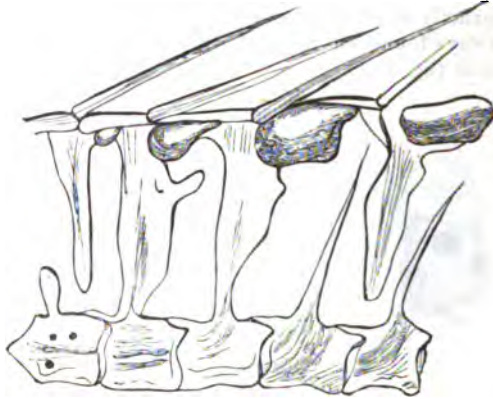


FIG. 7.—Five vertebrae of a Fish (*Lepidopus*) with exostoses (after Gervais).

A transverse section of a portion of the large tumour showed that the growth was composed of successive layers of a tissue resembling dentine, traversed by nutrient canals, each layer of this vaso-dentine being separated by a tract of more compact osseous tissue, as shown in fig. 8.

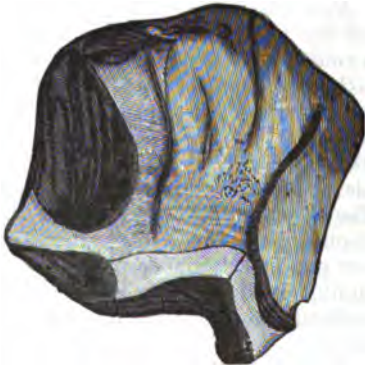


FIG. 8.—Exostosis of a Fish (*Pagrus unicolor*) growing from the occipital crest (one-third its natural size). The accompanying figure shows the resemblance histologically to vaso-dentine.

Tissue of this character enters largely into the formation of the hard parts of the skeleton of the majority of fish, more

especially in connection with the teeth, so that its occurrence in exostoses of fish is not more remarkable than osseous tissue in the morbid growths of mammals. Nevertheless, it is interesting to note that the only traces of this piscine tissue in animals other than fish are confined to the teeth of very few mammals, the extinct *Megatherium* particularly, and in the teeth of man only occurs as a rare pathological formation in the form of vascular dentine.

The museum of the Royal College of Surgeons contains the following interesting examples of exostoses in fish:—

The first one (fig. 9) is an example of an exostosis half an inch in diameter growing from the vertebræ of a cod-fish (*Gadus morrhua*). An important feature in this growth, which is made up of hard compact bone, is that it springs from the meeting-place of two vertebræ, that is at a spot corresponding to the intervertebral substance. The second example is that of an exostosis on the dentary bone of a Pike; it is finely spiculated and springs from the alveolar border of the bone. It has displaced two of the teeth inwards (fig. 10).



FIG. 9.—An exostosis in connection with the vertebræ of a Cod-fish.

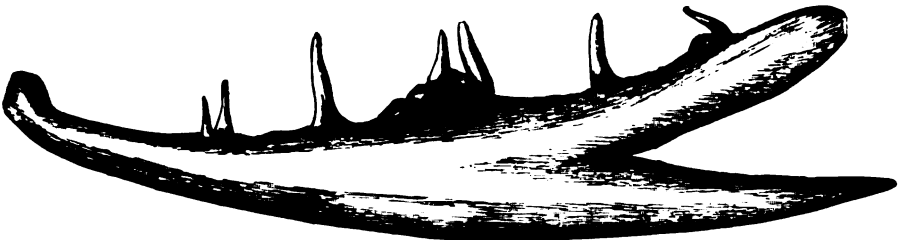


FIG. 10.—Exostosis on the dentary bone of a Pike (Museum of the College of Surgeons).

The third case is that of a heavy disc-shaped osseous tumour, about 2 inches in diameter, and half an inch in thickness, growing from the superior maxilla of a cod-fish (fig. 11). In its external appearance and internal structure it resembles the tumour on the vertebræ of the cod-fish before quoted.

The same museum possesses a portion of a large ivory-like tumour, which grew from the forehead of an ox, and appeared to

have had its origin in the frontal sinuses. It was spheroidal in shape, weighed upwards of sixteen pounds, and measures $8\frac{1}{2}$ inches in its greatest diameter. Its surface is tuberous, but hard and smooth like an elephant's tusk. The whole of the tumour has the microscopic structure of bone.

The same museum contains the ulna of a fowl, which is embedded, except at its articular surfaces, in a very compact bony tumour, which both fills its cavity and grows nearly an inch



FIG. 11.—Exostosis on the superior maxilla of a Cod-fish.

beyond its normal compact wall. The museum of Guy's Hospital possesses an interesting example of exostosis attached to femur of cat. It is represented of natural size on Plate XXIII. fig. 2.

Osseous tumours have been found connected with the nasal septum in the horse.

In one recorded case¹ the mass was distinctly pedunculated, measured $11\frac{1}{2}$ inches in circumference, and weighed 21 ounces. It had made its way into the antrum, causing absorption of the outer wall of the nasal fossa. On section it presented all the ordinary characters of bone.

In another instance an osseous tumour was safely removed from the palatal surface of the premaxillary bone of a three-year-old colt. The tumour had displaced the incisor teeth. It measured 4 inches in length, nearly $2\frac{1}{2}$ inches in width, and $1\frac{1}{2}$ inch in thickness. It weighed 5 ounces. In microscopical characters it conformed to the structure of true bone.

In the human subject exostoses have been known to break

¹ *Veterinarian*, vol. xxviii. p. 84.

from their attachment and lie loose in the cellular tissue. The following cases appear to be of this nature:—

(1) An exostosis, which was removed from a horse, weighed 27 ounces, and lay loosely connected by cellular tissue to the bones of the stifle joint (knee). It had been observed to increase in size from a hazel nut to 10 inches in diameter. It was surrounded by cartilage.

(2) An osseous tumour, loosely attached to the inner and front part of a horse's hock. The bony mass was of the size of an orange (*Veterinarian*).

The museum of the Royal Veterinary College, London, contains some specimens of exostoses removed from the skulls of horses. Three of them, formed of very hard dense bone, exactly resembling that which composes the "ivory exostoses" of human pathology, were removed from the neighbourhood of the petrous and mastoid portion of the temporal bone—a region of the human skull where osseous growths occur with extreme frequency. The largest of these tumours measures 8 inches in length, 5 inches in width, and 3 inches in thickness. Among them is one which grew on the inner aspect of the cranium. It is of less density than the others, and resembles pumice-stone in appearance. There is no variety of new formation so widely diffused as the bony tumour or exostosis. Its presence has been recorded in fish, recent and extinct, in amphibians, in birds, and in many varieties of mammals. The universal presence of osteomata is to be explained by the existence, in all vertebrate forms, of that peculiar substance which forms so large a part of the skeleton of lower animals, and, for a brief period, that of the highest types—hyaline cartilage.

ODONTOMATA.—An odontome is a tumour composed of dental tissues, arising in connection with teeth or germs of teeth. Up to the present time the only classification of these tumours in use is the very unsatisfactory one introduced by Broca in his *Traité des Tumeurs*, vol. ii., 1869, where he endeavours to arrange odontomes in classes according to the stage of development of the tooth at which the tumours probably arise. Almost every writer on tooth tumours, since Broca wrote his well-known work, have found occasion to complain of the eminently unsatisfactory

character of the classification adopted by him; but no one has attempted to improve matters by suggesting a better one. In this article I shall adopt the plan followed with regard to other tumours, and arrange them according to their histological structure.

The teeth of most mammals consist of three distinct structures—(1) enamel, which is of epiblastic origin; (2) dentine; and (3) cementum. The two last arise from mesoblastic tissues. To these must be added the modification of dentine, known as osteo-dentine.

I am unaware of enamel ever entering, in any considerable quantity, into the formation of an odontome, hence it is not necessary to make provision for it; this is very convenient, for, if such were the case, an odontome composed of enamel would have to be classed under the epithelial tumours, whereas now all the odontomes I am acquainted with consist of the other elements of the teeth, and strictly come among mesoblastic tissues.

Classification of the Odontomata.

- | | |
|-----------------|----------------------|
| 1. Cementomata. | 3. Osteo-dentomata. |
| 2. Dentomata. | 4. Mixed Odontomata. |

1. *Cementomata*—In this variety the bulk of the tumour is made up of cementum, often arranged in layers if the tumour be a large one. It is a tissue like true bone, slightly modified in structure, containing lacunæ and canaliculi. If the mass is very thick it may contain Haversian canals. Seeing that the teeth of ruminants contain a very large proportion of cementum, it need not surprise us to find that cementomata are especially frequent among them, and attain considerable proportions.

Broca¹ has described and figured some interesting examples of this variety in the horse; the abnormal masses were attached to the molar teeth and composed almost entirely of cementum; some of the examples mentioned by this observer are deposited in the museum at Alfort. It is curious to note that in some of these instances the tumours had become worn on one of their surfaces, having been used in mastication. Mr Charles Tomes² described an example of this variety of odontome connected with the molar of a horse. The mass

¹ *Traité des Tumeurs.*

² *Trans. Odonto. Soc.* 1871-72.

was five or six times as large as the tooth itself, and weighed ten ounces. On its upper surface it is in one place deeply worn and grooved by the opposite teeth in mastication. The great bulk of the tumour was in front of the molar to which it was attached. Examined microscopically, it was found to be composed entirely of cementum. The outside consisted of numerous parallel laminae of this tissue, not differing in any marked character from that which naturally covers the tooth fang in the herbivora. Inside this laminated covering there is a tissue quite devoid of anything like lamination, in which numerous bone corpuscles are found, and an abundance of those globular forms which are seen in secondary dentine, or in dentine of imperfect formation.

Other observers, as E. M. Rosseaux, Goubaux, and Magitot, have recorded instances of odontomata occurring in connection with the teeth of horses. Many cases reported by Magitot, however, were taken from the museum of the Veterinary School at Alfort, and have been already alluded to.

Tumours composed almost entirely of cementum are not confined to herbivorous animals. In fig. 12 is represented the left



FIG. 12.—An Odontome connected with the incisor of an Agouti. It is composed of cementum.

lower jaw of an Agouti (*Dasyprocta agouti*); attached to the root of the lower incisor is an odontome of fair proportions considering the size of the animal. On splitting the tooth and the tumour longitudinally the new growth was seen to surround the root of the incisor on all sides.

Sections of this hard substance were kindly prepared for me by my friend Mr Andrew, the examination of which very clearly shows that the tumour is composed chiefly of cementum; small patches of dentine can be detected here and there throughout the mass, and dark areas resembling interglobular spaces, but more than three-fourths of the tumour consists of cementum.

2. *Dentomata*.—These tumours are made up chiefly of den-

tine, but usually of the variety known as osteo- or secondary dentine.

This substance occurs largely in the teeth of the Walrus and Cetacea (Odontocetes). It is very frequently developed in the tusks of elephants consequent on irritation, and in the pulp of human teeth when attacked by caries.

Several examples of dentomata have come under my notice.

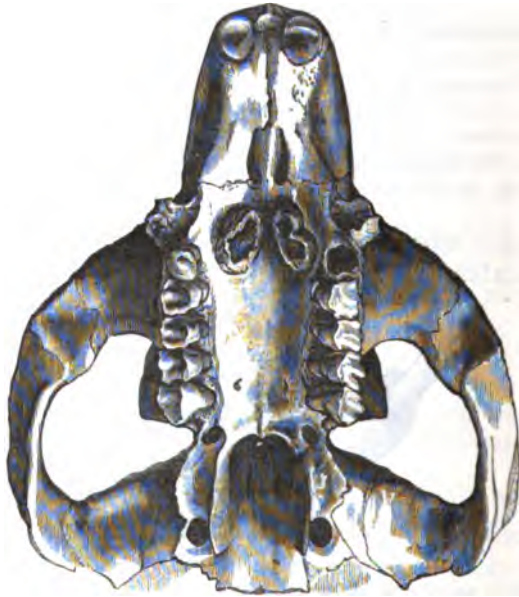


FIG. 13.—Hard palate of Marmot. Odontomes connected with the roots of the upper incisor teeth appearing on the hard palate.

The accompanying figure (fig. 13) represents the hard palate of a Himalayan Marmot with two moderate-sized odontomata in connection with the roots of the large incisor teeth. These tumours, when examined under the microscope, were found to be composed of dentine and cementum indiscriminately mixed, but the dentine preponderated.

In one remarkable case I found no less than four of these growths in the mouth of a Prairie Marmot (*Cynomys ludovicianus*), each one in connection with the root of an incisor tooth. Those in the lower jaw were much larger than the growths in the upper one. The arrangement of the lower incisor tooth of the

left side is represented in fig. 14, where the outer plate of the maxillary bone has been cut away in order to expose the odontome *in situ*.

The tooth projects very little above the alveolar margin, and has a very thin cap of enamel; passing backwards it lies below the inferior dental canal until its extremity reaches the coronoid process, where a considerable cavity exists for its reception. All that portion of the tooth which lies hidden in the bone presents a rugged surface. At the base of the coronoid process the tooth ends in a



FIG. 14.—Lower jaw of a young Marmot, with a large odontome connected with the root of the lower incisor tooth.

large odontome, which mounts upwards as high as the summit of that process, which has become hollowed out and thinned to contain it, the pressure of the growth having caused considerable atrophy of the bone; in some places the maxilla is so thinned as to yield to the pressure of the nail.

Mr J. J. Andrews has been good enough to make some sections of the growth, and to illustrate its microscopical appearances and minute structure by some admirable drawings. The following is his description :—

“The tumour has a slightly lobulated appearance, as if made of spherules; the surface in places presents irregular markings. It measures in length three-fourths of an inch, in width one-third of an inch, and is half an inch in depth. Remembering that the lower jaw is only 3 inches long by 1 inch in the widest part, this tumour is of very considerable size relative to the bulk of the animal. The normal truncated hollow seen in these teeth is completely filled with secondary dentine, except in a few irregular spaces here and there. The main mass of the growth is dentine, some parts of it displaying interglobular spaces; patches of enamel may be seen in some part of the tumour, and a small quantity of cementum surrounds it, and in places runs into the interior.”

Fig. 15 shows a section of the tumour magnified about ten times. At the base is seen the small pedicle by which the tooth and odontome were attached.

As far as I can learn, odontomata, made up entirely, or in chief part, of dentine, such as is ordinarily seen in the teeth, is very rare in man.

An instance of this, however, is afforded by a case recorded by Dr Forget,¹ which occurred in a man aged twenty. The tumour was of the size of an egg, and its surface was covered with minute tubercles, which were invested by a layer of enamel. The tumour was com-

¹ *Dental Anomalies.*

posed of dentine, but a small amount of enamel and cementum were present.

3. *Osteo-dentomata*.—Structurally these are formed of hard tissue, traversed by canals which contain blood-vessels. The dentinal matter may be deposited in a globular form ; from the



FIG. 15.—Section of an odontome from a Marmot (magnified about ten times).

vascular canals, tubules, resembling in their size and mode of ramification the dentinal tubules, pass off and lose themselves indefinitely in the surrounding hard structure.

Tumours composed of osteo-dentine are occasionally found connected with the tusks of elephants. The museum of the Royal College of Surgeons possesses some very good examples.

The museum of the Odontological Society of Great Britain has an excellent specimen also in connection with the tusk of an elephant. This has been examined microscopically by Mr C. Tones, and found to be composed of osteo-dentine.

A most beautiful specimen, probably belonging to this class of odontomes is figured by Magitot.¹ The tumour, which belonged to Professor Loraine, was removed from the side of the tusk of a young white elephant of Siam. It was an enormous ovoid, tuberculated mass, measuring 20 centimetres in length, and 9 centimetres transversely.

Large masses of osteo-dentine are often found in the interior of the tusks of elephants, consequent on the irritation of the pulp by spear-heads, bullets, &c. The odontome represented in fig. 16 is developed around the tusk of an elephant, which has



FIG. 16.—Odontome in connection with an Elephant's tusk.

become stunted in growth as a consequence. The specimen is in the museum of the Royal College of Surgeons, and I have had no opportunity of examining it microscopically. Most of these tumours are composed of osteo-dentine. The museum contains several other growths of this character.

4. *Mixed Odontomata*.—Under this division will be inclined all those tumours where the three dentinal tissues—enamel, dentine, and cementum—are so intimately mixed that there is not sufficient preponderance of any one tissue to distinguish the tumour and place it under any of the previous headings.

To this class most odontomata occurring in the human

¹ *Anomalies Dentaire*.

subject must be referred. I have gone very carefully over the recorded cases of these tumours, and find that the majority are composed of cementum and dentine in varying proportions; in some of them a variable quantity of enamel was detected.

The remaining cases will be described in relation with their bearing on the origin of these interesting tumours.

Virchow quotes Leisering concerning a very curious tumour found developed in the region of the last molar tooth in the inferior maxilla of a calf. The tumour had distended the alveolus, and had acquired a polypoid form, measuring 3 inches by $7\frac{1}{2}$ inches. The surface was tuberculated, each little papilla being formed of dentine covered with an enamel cap. The tumour itself was composed of connective tissue, vessels, and dentine. Robin¹ found, in the inferior maxilla of a child two years and a half old, a tumour, fibrous in appearance, with papillæ, presenting distinctly dentine and enamel. It seems to me exceeding probable that in these two cases we have to deal with odontomata in an early stage. The following example seems to be of a similar nature:—

A hybrid goat (a cross between a Nubian and a common goat),



FIG. 17.—Section through the skull of a Goat. An odontome in the course of formation.

when three months old, was found to exhibit marked enlargements on either side of the face, in the neighbourhood of the antra and the angles of the lower jaw. About one month later the animal died.

On making a section through the skull, each antrum was found occupied by a very thick-walled cyst, in the interior of which was a molar tooth (probably the first permanent); the cyst-walls were an inch in thickness. Its general appearance on section is shown in fig. 17. There can be little doubt that the parietes of the cyst are really the walls of the tooth follicle enormously thickened; on making sec-

¹ *Mém. de la Soc. de Biologie*, 1863, ser. iii. t. iv. p. 301.

tions of the part, it is found to be made of layers of connective tissue undergoing ossification, agreeing in structural details with the tooth sac of a healthy goat compared with it.

The growths in the lower jaw were situated near the angle, and agreed in structure with those of the upper jaw, but did not contain teeth. Altogether there were four of the curious cysts in this goat; the surrounding bony tissue was so soft that it could be cut with a knife, yet the other parts of the skeleton were firm and hard.

Soon after finding this case I had an opportunity of inspecting a similar specimen at the Royal Veterinary College, London, also in a goat, but the abnormal masses were confined to each lower jaw, and were thought to be sarcomata. Virchow¹ has recorded a specimen of this nature under the name of a soft osteoma in the jaw of a goat. These are the only three examples I am acquainted with, probably they will be found not infrequent if carefully looked for. They possess a considerable amount of interest, for they shed some light on the origin of odontomes. A tooth is built up of three structures of totally different origin—enamel from the enamel organ, dentine from the papilla, and cementum from the alveolar dental periosteum and tooth follicle. Cementomata, or tooth tumours composed almost entirely of cementum, are most common in herbivora; they are generally attached to, or surround the molar teeth, and often present a laminated arrangement (see especially Mr Tomes' case referred to on page 432). I am strongly of opinion that in the tumours lodged in the jaws of these goats we have to deal with cementomata in the course of development, and that had they lived these hypertrophied follicles would probably have become hard tumours.

Hypertrophy of the dentine papillæ in the same way gives rise to a dentomata, but as regards abnormality of the enamel germ we are in total ignorance.

ANGIOMATA.—Angiomata are tumours consisting of blood-vessels held together by connective tissue in varying proportions. They include nævi, erectile tumours, and aneurism by anastomosis.

They are usually divided into two classes, *simple* and *cavernous*.

¹ *Cellular Pathology*, chap. xix.

1. *Simple Angiomata*.—In this class the new vessels resemble normal arteries, veins, or capillaries, in a dilated and tortuous condition, bound together by connective tissue. Some of the vessels are of new formation, but many of them must be considered as dilatations or enlargements of pre-existing vessels.

Angiomata are rare in animals. Röhl insisted on this in 1856, and showed that the most frequent seats of their manifestations are the lips, eyelids, mammary glands, and prepuce.

2. *Cavernous Angiomata*.—In this class it is usual to include venous vascular tumours and aneurism by anastomosis. They consist of an erectile cavernous tissue, such as exists normally in the corpus spongiosum, the comb of the cock, and the knob on the beaks of certain water-fowl, notably the swan. The structure of these appendages serve well as a physiological type for vascular tumours. Virchow cites cases from Gurlt¹ of aneurism by anastomosis in the horse and dog. In the horse the upper lip was the part effected; the angioma was of the size of a five franc piece. The part was easily injected from the veins, and the growth occupied the whole thickness of the skin.

Sims Woodhead² mentions that although angiomata are not very frequently met with in the liver of the human subject, yet in the liver of the domestic cat it is of common occurrence. It may be detected, as a rule, near the surface, and may be seen shining through the capsule as a purple or dark claret-coloured patch. Not only in the cat, but in cat-like animals, the *Felidæ*, this condition may occasionally be seen; but the morbid patches are, as a rule, so small, rarely exceeding a pea in size, that, unless especially looked for, they are very liable to be missed. The most marked case of cavernous angioma that has yet come under my notice occurred in a dog fourteen years old. In this instance six tumours, of the size of walnuts, occupied the liver substance, and formed prominences on its exterior. They were of a dark purple colour, and when cut into were found to consist of cavernous spaces filled with blood. The morbid masses had given rise to no symptoms during life.

¹ Gurlt, *Lehrb. der Path. Anat. der Haussäugethiere*.

² *Practical Pathology*.

MYOMATA.—Myomatous tumours consist essentially of new-formed muscular fibres. They are limited to certain regions of the body. Two varieties are recognised—*Leiomyomata*, or smooth-muscle tumours, and *Rabdomyomata*, or striated muscle tumours.

Leiomyomata are met with in the uterus, where they form rounded masses, at times of considerable size. In this situation the bulk of the tumour is made up of fibrous tissue, constituting a fibro-myoma. On transverse section they offer a peculiar whorled or concentric arrangement, which is at once peculiar and characteristic.

Fibro-myomata are not unknown in animals. Instances have been recorded in cows. Virchow, in his great work on "Tumours," speaks of hard growths of all kinds, which have been found in connection with the ovaries, vagina, and uterus of animals. These have been habitually described as sarcomata or fibroids. He quotes facts from the works of Gurlt and Förster as evidence of the occurrence of fleshy tumours, developed in the walls of the uterus, especially between the muscular layer and the mucous membrane, in the mare, cow, and pig. Leisering found numerous fibroids in the submucous tissue of the vagina of a bitch, as well as fibroids in the uterus of a cow. Virchow concludes the chapter by stating that the details of the intimate structure of these tumours, occurring in animals, requires more precision, and it remains for further researches to establish their nature. Myomata are certainly not common in animals. One undoubted case has come under my notice in a baboon, where the histological details were perfectly characteristic of a leiomyoma. The body of the uterus seemed to form part of one general tumour, and was very much enlarged. The Fallopian tubes and ovaries of each side were involved, and in part incorporated in the walls of the uterus.

Undoubted cases have also occurred in mares, cows, and the vagina of bitches, which seems to be a frequent situation for such growths in the form of polypi.

It is exceedingly probable that many of the tumours described as fibrous were in the first instance leiomyomata, which have retrograded into fibrous tissue (see page 419).

NEUROMATA.—It is customary to apply the term neuroma to

almost any growth connected with a nerve. In reality the name should be restricted to tumours, composed, in the main, of new-formed nerve fibres. In man, the commonest tumours connected with nerves are fibromata or myxomata springing from the connective tissue (perineurium and epineurium) of the nerve. The



FIG. 18.—Stump of fore-arm, three years after amputation, showing bulbous enlargement of the ends of the median, ulna, and musculo-spiral nerves.

only tumours in which new-formed nerve fibres have been detected with any degree of certainty are those bulbous enlargements which form at the proximal end of a divided nerve. Thus, in the stump of the fore-arm represented in fig. 18, considerable enlargement has taken place at the ends of the median, musculo-spiral, and ulna nerves. These bulbous enlargements of nerves may be occasionally seen in horses, for, on account of certain forms of incurable lameness, the veterinary surgeon divides and removes usually an inch of the plantar nerves, thus depriving the foot of sensation, and enabling the horse to work in spite of the diseased condition of the feet.

If the legs of a horse, which has been nerved some time previously, be examined, the proximal ends of the nerves, cut in the operation, may sometimes be detected as hard rounded knots through the skin. When dissected, and examined in detail, they are found in some cases to correspond in every way with the conditions of the nerves in an amputated stump in man. My first impression was that this statement was universally true, but find that it is not so; indeed, in the majority of "nerved" horses, the formation of bulbs on the proximal ends of the divided nerves is an exception rather than a rule; and that the more clumsily neurotomy is performed, the more likely is the operation to be followed by bulbing of the proximal end of the cut nerve. Horse dealers are able to detect horses which have been "nerved," not so much by finding the hard knots under the

skin, as by sticking a pin in the foot immediately above the coronet.¹

I have now, on several occasions, had the opportunity of dissecting the stumps of limbs taken from wild animals whose legs have been caught in traps, shot, or bitten off by other animals, or their nerves cut designedly. The specimens include beavers, pigs, porcupines, frogs, rats, rabbits, dogs, cats, and horses, but no bulbings could be detected, although in some cases the injury had occurred years before. In cats and dogs, submitted to the operation of neurotomy, bulbing is by no means the universal condition of the proximal end of the divided nerve. If, however, the nerve be divided, and the proximal end be irritated by applying a silk ligature to the nerve, or inserting a small fragment of wood to act as a foreign body, an enlargement is almost sure to follow. The best bulbs are produced by ligaturing a nerve "in continuity," and of all nerves the vagus is the one that shows the conditions best.

Whether these facts will apply to the human subject is worth considering. I have devoted some attention to the subject, and my limited experience induces me to believe that enlarged ends of nerves in amputations are more common where suppuration has been most profuse and healing long delayed, or the nerves have become adherent to bone, or bound up in the cicatrix, and probably in some cases included in a ligature applied to an artery on the face of a stump. Bulbs on cut nerves do not attain sizes in proportion to the nerve to which they belong. Small sensory nerves, in a stump, may have relatively very large bulbs. Finally, there is little reliable evidence that there is an actual growth of nerve fibre in the bulbs.

SARCOMATA.—The term sarcomata is applied to a group of tumours which conform histologically to immature connective tissue, that is, the cellular constituents predominate over the intercellular substance. In this respect the structural details agree with the connective tissue of the embryo.

Sarcomata invariably arise in structures belonging to the connective tissue group, fibrous, cartilaginous, osseous, mucoid,

¹ If, as frequently happens, the cut nerve reunites, a bulb is sure to arise. This must not be confounded with the bulbs mentioned in the text

lymphoid, or adipose tissue, and in neuroglia. Hence they may occur in any part of the body, and are widely diffused throughout the sub-kingdom Vertebrata. These tumours are usually very vascular, but lymphatics have not been shown to exist in them. They are liable to secondary changes, mucoid and fatty degeneration, liquefaction, ulceration, and hæmorrhage.

Classification of the Sarcomata.

- | | |
|---------------------------|-----------------------------|
| 1. Round-celled. | 3. Gliomata. |
| (a) Small round-celled. | 4. Myeloid or Giant-celled. |
| (b) Large round-celled. | 5. Melanotic Sarcomata. |
| (d) Lympho-sarcoma. | 6. Myxomatodes. |
| 2. Spindle-celled. | 7. Alveolar Sarcomata. |
| (a) Large spindle-celled. | 8. Osteoid Sarcomata. |
| (b) Small spindle-celled. | 9. Psammomata. |
| (d) Chondro-sarcomata. | |

1. *Round-celled Sarcoma.*—These are of very simple structure; consist almost entirely of round cells and vessels; the inter-cellular substance is very scanty; the cells are small and enclose a rounded or oval nucleus.

The museum of the College of Surgeons possesses a typical example of this kind of tumour. "It is a golden plover with a sarcoma lying beneath the skin of the breast, about an inch and a half in diameter; it is encapsuled, and its section is homogeneous. Under the microscope, the tumour appeared composed of round cells, each of which was enclosed within the meshes of a reticulum of fibrillar tissue."

Dr Creighton has given a detailed account of a sero-sanguineous cyst, which occurred in the neck of a retriever dog. The cystic interior contained a considerable quantity of clear brownish fluid containing a large number of red corpuscles, leucocytes, and some large cells filled with yellow granules. The walls of the cyst conformed to the type of a round-celled sarcoma.¹

The *Brit. Med. Journal* for 1883² contains two accounts of round-celled sarcomata in birds. A fowl, one year and a half old, presented a tumour on the neck, immediately below the beak. It finally attained the size of a cricket ball, and weighed nearly seven ounces. The disease recurred two months after removal. Histologically it was composed of round cells in a fibrillated matrix. The cells were equal in size to a red blood-corpuscle.

The second case, also in a common fowl, grew around the margin of the left eye, forming a thick prominent ring. There was also a growth the size of a pigeon's egg in the lower third of the neck. The tumours, which were made up almost entirely of small round cells with a few

¹ This *Journal*, vol. xiv.

² Report by Mr Hathaway, examined by Mr Bowlby.

spindle-shaped ones, formed an infiltrating mass between the layers of the subcutaneous tissue.¹

Through the kindness of Mr Shave of the Royal Veterinary College, London, I have been able to examine sections of a small round-celled sarcoma, which was found connected with the colon of an ass. There were deposits in the liver, spleen, and on the posterior surface of the diaphragm. It was one of the most typical examples of a round-celled sarcoma that has yet come under my notice in an animal.

Lympho-Sarcomata.—These tumours are a variety of the small round-celled sarcomata. Structurally they resemble a lymphatic gland, being made up of a reticular stroma with ramifying cells (adenoid tissue) containing round cells in the meshes of the stroma. These growths increase rapidly, and give rise to secondary formations.

Mr Eve² reported a case of this nature which occurred in a *Dasyurus* (a marsupial from Van Dieman's Land). The tumour consisted of an agglomeration of enlarged and coalesced lymphatic glands, removed from the abdomen. The spleen was connected with the upper part of the tumour, the two equaling two-thirds the weight of the animal.

The tumour consisted of closely aggregated round cells resembling lymph corpuscles; its vessels were abundant and had no proper wall. Some rounded masses 1 to 2 inches in diameter were found in the liver, lung, and colon.

A similar condition came under my notice also in a *Dasyurus*. In this example the adrenals were affected by the growth. Lympho-sarcomatous masses are frequently found in the horse, associated with the glands of the mesentery and those of the lumbar set. In some of these cases the morbid mass weighs many pounds. These growths disseminate themselves, and are therefore to be regarded as malignant; secondary deposits are most frequently seen in the liver and spleen. In the latter organs the morbid masses vary in size from that of a hazel nut to a deposit as large as an orange; usually they are of a greyish-white colour, and of moderate consistence. The nodules in the liver are of smaller size and disseminated through the organ. They do not differ histologically from the primary masses.

¹ Reported by Mr George Parker.

² *Path. Soc. Trans.*, vol. xxxiii. p. 432.

Several examples of lymphoid tumours occurring in horses have come under my notice, the most frequent being in the lumbar gland, immediately around the anterior mesenteric artery. Others occurred in the mediastinum. Calcific deposits are not uncommon in large tumours of this kind. It is not unlikely that the frequency of lymphoid masses in the neighbourhood of the anterior mesenteric artery in the horse is to be accounted for by the frequent presence of the *strongylus armatus* in the neighbouring fibrous tissue of the tunica adventitia of the aorta, celiac axis, &c., acting as an irritant.

2. *Spindle-celled Sarcomata*.—In this variety the predominating shape of the cells is spindle-form. Tumours of this type are, as a rule, much firmer than the round-celled sarcoma.

Dr Creighton has reported a typical case of this variety, which was removed from the head of a dog at the Brown Institution, July 1875.

There was a cavity in the interior of the growth filled with a clear brown fluid, which fluid contained a number of cells of very large size, which exhibited amœboid movement (the fluid was examined whilst still warm). The interior of the cavity was in places crossed by trabeculæ, rounded in shape, and about a line or two in thickness. The structure of the walls of the growth was that of a spindle-celled sarcoma.

This form of new growth occurs with tolerable frequency in the dog, and nearly always is situated in the subcutaneous tissue.

It is very interesting to reflect that even fish are subject to spindle-celled sarcomata. This fact is well illustrated by a specimen in the museum of the Royal College of Surgeons, London; it is a golden carp with a tumour growing from the posterior border of the dorsal fin, as shown in fig. 19. The morbid growth is about the dimension of a filbert nut; it has been examined microscopically, and found to exhibit all the characters of a spindle-celled sarcoma.

There is one very curious feature connected with the spindle-celled variety of sarcomata which must be considered, and that is their disposition to form cartilage, especially when they occur in the testis. Mr Butlin¹ points out that cartilage occurs in greater

or less quantities in half the number of these cases. One of the most interesting features in these "Lectures" of Mr Butlin is his endeavour to separate the enchondromata of the testis from cartilage tumours in general, and to show that they are really to be regarded as chondrifying sarcomata. This view of these growths is very important, for it explains why so many of these tumours of the testis exhibit true malignant tendencies, a condi-

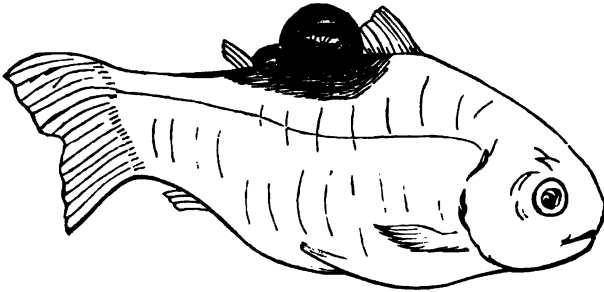


FIG. 19.—A Golden Carp with a spindle-celled sarcoma in connection with its dorsal fin (Museum of the College of Surgeons).

tion of things certainly not the rule in enchondromata occurring elsewhere.

Growths similar in character affect the testes of animals, as the following case will testify:—

The *Veterinarian* for 1850 contains a well reported case of an ossifying enchondroma connected with the testicle of a horse, by Joseph Gamgee. The testicle was removed from a four-year-old horse. The animal was the size of several colts, and did not suffer any particular inconvenience from the presence of the diseased organ. The gland nowhere presented its normal structure, the tissue being soft, of a red colour, and ill-defined in structure, and was connected with a tumour of moderate hardness, about the size of an orange.

The growth was of pale yellow colour when seen in section, finely and irregularly lobulated, and contained three cysts. Cartilage was visible in the centre of the cut surface, and could be felt extending into the substance of the tumour. On microscopic examination, the tumour was found to contain fat, fibrous tissue, cartilage, and bone.

When critically examined, the cartilage cells, as they approached the surface, were found to become much flattened, and to degenerate into, or at any rate to become intimately blended with, the adjacent fibrous tissue and fat. The matrix appeared in some situations homogeneous and transparent, in others granular; and at wide intervals a few delicate fibres might be seen winding their course between the cells. A transverse section of the bone exhibited imperfectly the ordinary structure of osseous tissue.

If the details of this remarkable case be compared with the description of similar tumours met in the testis of man, and be criticised in the same manner in which Mr Butlin has discussed the cases in his lectures, there will remain little doubt that this tumour belongs to the same category.



FIG. 20.—Tumour containing cartilage C., connected with the testicle of a horse (after Gamgee).

It is possible that the following case, reported by Virchow,¹ is of sarcomatous nature. A bitch had a large ossifying enchondroma of the mamma; there was also a large tumour in the omentum, softened in the centre after the fashion of a cyst, and filled with liquid. There were numbers of small nodules in the lungs, on the pleura and in the mediastinum. Many of the nodules in the lung had spread by way of lymphatics, so as to communicate with neighbouring nodules, and form a kind of network throughout the lung tissue.

Histologically these nodules were found to be composed of fibrous hyaline cartilage which had commenced to calcify in the centre. The masses in the lymphatic vessels had commenced to chondrify in the middle, but at the periphery of these deposits there were collected groups of cells, but no intercellular substance.

3. *Gliomata*.—Gliomata are tumours formed on the type of neuroglia, the delicate connective tissue found in the central nervous system. Histologically these tumours are composed of a fibrillated intercellular substance, the fibrils of which, when isolated by teasing, will be found exceedingly delicate. Dotted, in this matrix are small round or slightly oval nuclei, which in

¹ *Pathologie des Tumeurs*, tom. i. p. 524.

teased preparations from fresh specimens will be found to possess delicate ramifying processes.

Gliomata exhibit very often patches of hæmorrhage and caseation in their interior. In the human subject they are locally malignant, and have marked infiltrating propensities, but do not often reproduce themselves in internal organs.

Gliomatous tumours are not by any means common in animals. A very marked case came under my notice in the right eye of a bonnet monkey, aged about 8 months (fig. 21). The eyeball was much enlarged, there was considerable proptosis, the cornea being bulged forward in a curious fashion, and there was œdema of the eyelids. The morbid mass entirely filled the interior of the globe, but in no spot had it broken through the tunics. The lens was opaque. The lymphatic glands were not affected. On making a section through the globe, spots of hæmorrhage and caseation were visible. Under the microscope, in the best preserved portions of the tumour, the structure, typical of a glioma, was distinctly obvious. The cells were small, for the most part round, and very numerous.

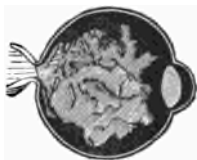


FIG. 21.—Section of the eyeball of a very young Bonnet Monkey affected with glioma.

The museum of Guy's Hospital contains, amongst its specimens of comparative pathology, two examples of sarcomatous tumour of the eyeball, one affecting the retina of a horse, the other that of a sheep. Through the kindness of the curator, Dr Goodhart, I have been able to examine the histological characters of these tumours. The growth in the eyeball of the horse is a typical glioma, and the specimen shows admirably the connection between the tumour and the retina, notwithstanding the fact that it had been in the museum certainly thirty-five years, and how long before that time it is impossible accurately to determine.

In the case of the sheep the true characters of the growth cannot be so easily determined. In parts it looks like a glioma, in others it resembles melanotic sarcoma.

4. *Myeloid Sarcomata*.—This variety of connective tissue tumours is characterised by the occurrence in large numbers of giant-cells, the peculiar multinuclear bodies found in the normal

condition in the medulla of a long bone. It must be admitted that very many sarcomata, springing from, or growing in the neighbourhood of bone, contain myeloid cells, yet do not come under the definition of myeloid. A very good example of this kind of growth is an osteoid tumour on the leg of a rat, described on page 456.

Butlin lays down the following definition for a myeloid tumour:—"The giant-cells should constitute about four-fifths of the bulk of the growth, or be present in such numbers that they decidedly affect the colour of the tumour, colouring it a maroon red."

Tumours, corresponding to this character, must be very rare in animals. I have never met with any, or found any examples recorded.

5. *Melanotic Sarcoma*.—This class comprises sarcomatous formations which contain deposits of pigment. The pigment, which may be either black or brown, may be partly in the tumour-cells, partly in the fibrous matrix and walls of the vessels. The pigment is usually in the form of amorphous granules. This form of morbid growth is especially frequent among white horses, oxen, and dogs.

Hunter removed one of these tumours, and his prowess in this direction is attested by the specimen now in the Hunterian Museum. It is thus described in the catalogue:—

"Section of a melanotic tumour removed from the neck of a horse. It is deep black throughout, moderately firm, lobulated, and on its cut surface rather shreddy."

Hunter's account of the case is given in the catalogue. I make the following selections:—

"The tumour was on the near side of the neck, lay immediately on the inside of the jugular vein, where they commonly bleed; the vein was plainly seen passing over it. It was about 8 or 10 inches long in the direction of the neck, and about 4 or 5 thick. It was loose, not attached but by loose cellular membrane.

The tumour was of a very dark colour, and when cut into and squeezed, a black fluid, exactly like ink, came out on the cut surface. It blackened the water it was steeped in for a considerable time."—*Hunterian MS.*

The animal did not survive the operation.

The same magnificent collection contains two other examples of melanotic sarcomata affecting the tails of horses (Plate XXIII.,

figs. 3 and 4). Also the udder of an almost white cow which contains a tumour about 3 inches in its long diameter, and uniformly black. The skin of the udder is mottled with numerous pigmental blotches.

Virchow has collected facts and recorded them in his great work on "Tumours" regarding the especial liability of white horses to melanotic sarcomata. The neighbourhood of the anus or tail are favourite situations for these masses. He has met with and examined tumours from both these situations, and found them to exhibit sarcomatous structure, but the cells are fewer than in man. The growths on the tail form large excrescences like mushrooms, with little disposition to ulceration or metastasis, but later writers, especially Cornil and Trasbot, show that secondary deposition is the rule. Virchow states that Brugnone appears to have been the first to notice this affection in horses under the names of hæmorrhoids. Noack, in 1826, described the affection, and gives some figures illustrating the condition in white horses.

Carswell gives some beautiful illustrations of melanotic tumours in horses, and states that "the largest masses have been found in the loose cellular tissue, and have been known to weigh from 20 to 30 and even 40 pounds."

Gluge mentions the occurrence of these growths in horses (white or grey), rabbits, rats, mice, cows, asses, mules, and cats, and mentions that Otto has seen the disease in a stag. Gluge found no structural difference in the growths in the horse or man. In animals it affected chiefly the anus and reproductive organs.

Lebert describes and gives some good drawings of melanosis in the horse, having seen the pigmented masses occupy the surface of the lungs and pericardium in the shape of grapes, varying in size from a small to a large nut.

The spleen and kidneys also contained melanotic tumours, and a certain number existed in the heart. The masses had a sepia tint. Lebert speaks of having many times seen melanotic tumours in horses. Barlow has made the following remarks on the subject:—

Melanosis among the lower animals is almost exclusively confined to grey horses. The disease often appears locally at first, and manifests itself on the external parts of the body covered by dark coloured skin, as the under surface of the tail, anus, and margins of the eyelids. When of longer duration, many of the internal organs, but more especially the mesentery, become involved, and instances have been seen where the voluntary muscles have been extensively affected. It does not evince any of those characters, which in the human subject are taken as indications of malignant disease; on the contrary,

unless exposed to mechanical injury, it does not ulcerate or soften, and when a tumour is freely cut into and partly removed, the portion still remaining will readily heal. Professor Dick once amputated a horse's tail as high up as the second vertebral segment. The melanotic mass weighed fifty-six pounds. In the operation a large amount of diseased tissue was left in connection with the anus and croup. The cut surface healed as readily, so far as could be judged, in quite as short a time as an incision of similar extent would have done if made in completely healthy tissue.

By far the most elaborate investigation of this subject has been made by Cornil and Trasbot.

These authors divide the melanotic tumours of horses into two classes—Melanotic Fibromata¹ and Melanotic Sarcomata.

In this section the sarcomata only will be considered. It is the

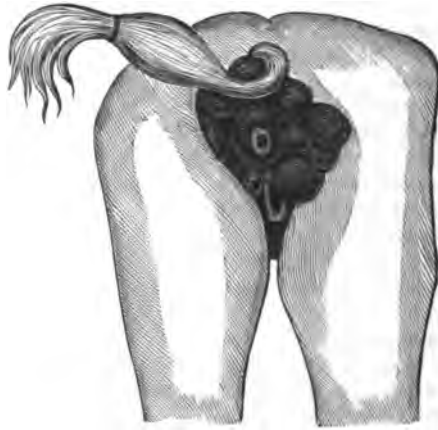


FIG. 22.—Melanotic Sarcoma around the anus of a mare (after Cornil and Trasbot.²)

most common neoplasm in the horse, and has a remarkable tendency to generalisation. The primary tumours are almost invariably developed in the subcutaneous tissue of the anus (fig. 22), the under surface of the tail, the external organs of generation, the sheath in the male, or the mamma in the female. Out of thirty-seven observations all but five commenced in these regions. The age of the horses varied from four to seventeen years; the prevailing colour was white or grey, only two were black.

The tumours are always very small at the commencement, acquire

¹ *Vide* page 420.

Noack gives a similar illustration.

with a time a very variable size, from a pea to a man's fist. Usually their number is considerable, united or adherent, forming tuberous masses, and continuous with the neighbouring parts by connective tissue. At the commencement they are situated exclusively in the skin and subcutaneous tissue. Superficially their colour is slate-grey, but completely black on section; a liquid mass may be squeezed out by compression, having the colour of sepia. In consistence they are sometimes as soft as a medullary cancer, in other cases they may be as hard as scirrhus, the difference in density varying with the proportion of fibrous tissue.

The centre of one of these masses is softer than the periphery, sometimes forming actual cavities. Occasionally they ulcerate.

Histologically examined, the tumours are composed of parallel fasciculi of fibrous tissue, enclosing cells more or less fusiform in shape enclosing pigment. In the broken down central portions of the tumours the cells are of all shapes and sizes, branching, fusiform, or spheroidal, containing black pigment. In the older and most deeply coloured portions of the tumours the elements adhere more or less to one another, and approach more to a spherical form, but they always maintain the same disposition and characters.

Plate XXIII. fig. 5, taken from Cornil and Trasbot's work, gives a fair representation of the microscopical appearance of these growths.

Usually the tumours grow slowly, they may remain passive many years, then take on active growth, but as a rule they slowly increase throughout the animal's lifetime.

Ulceration.—The tumours often soften in some part or other, and, forming open ulcers, hideous and repulsive, discharge a dirty black liquid. Sometimes these growths when cut into will cicatrise. In one curious case which Cornil and Trasbot followed for five years, in a white horse which possessed a large melanotic mass, it would ulcerate and remain open for several weeks in spring.

The Secondary Tumours.—These may be developed in every organ, or in almost every situation where cellular tissue is loose and abundant; the pelvic cavity, the entrance to the thorax, lymphatic glands, and muscles. The secondary tumours occur also in the liver, spleen, lungs, and supra-renal capsules. They affect the serous membranes, the brain and spinal cord, rarely the bones, and exceptionally the kidney, the substance of the heart, and the mucous membranes. In the connective tissue they may acquire a considerable size, weighing as much as 8 or even 20 pounds. In form they may be spheroidal, elongated, or fusiform, but always with tuberous rounded extremities. They may surround vessels and nerves, and thus interfere with their functions. In structure they agree with the primary tumour.

The lymphatic glands are affected always, and present a slate-grey colour superficially, but are entirely black on section. They are hard, and resistant to cutting instruments. The pigment at first affects only the connective tissue of the glands, but later it invades their substance.

Next to the glands the muscles are most frequently affected by the

dissemination of these tumours, in the form of very small discoid and lenticular masses developed on the surface and in the intermuscular fasciculi. These masses are sometimes united by pigmented strands of connective tissue, so that on section a muscle bears a resemblance to a piece of mahogany.

In the serous membranes these small lenticular nodules are dotted over the surface; the nodules are often of the size of a nut, and extend into the subserous connective tissue.

The spleen is affected with extreme frequency, and often to such an extent that its size is doubled; in some cases it has weighed 30 or 40 pounds. In the liver, secondary masses are met with great frequency and of very large size. In the lungs the tumours are generally globular in form; in size vary from a nut to an ordinary apple. When occurring in the cranium or spinal cord, they are intimately associated with the contained organs. They have been seen in the spinal canal of a mule. Any organ in the body is liable to be secondarily affected.

It is interesting to note that the disease is not contagious. Cornil and Trasbot have made a great number of experiments, inoculations, injections in the veins, grafts in the subcutaneous tissue, and with liquid taken from the tumours in the living animals, or immediately after their removal. The experiments were tried on horses and dogs, but nothing developed. The grafts in horses always set up suppurations and were expelled. In the dog the graft remained surrounded by a zone of induration, but did not further develop.

After careful perusal of the elaborate article of Cornil and Trasbot, I have sought out a great number of cases incidentally recorded in veterinary literature; they go to substantiate the views of the French writers.

The following list includes the chief writings on this interesting subject:—

GOHIER, *Mém et Observ., sur la Chir. et la méd. vétér.*, Lyons, 1813, t. i. p. 324; C. A. NOACK, *Diss. inaug. de melanosia cum in hominibus, tum in equis obveniente*, Lip. 1826, tab. 1-11; CARSWELL, *Path. Anatomy* (Melanoma, pl. i.), 1838; LEBERT, *Traité d'Anat. Path.*, tome i. pp. 116, 121, pl. xv., 1857-61; GLUGE, *Atlas der Path. Anat.*, liv. iii. taf. i., 1750; BARLOW, *Ed. Monthly Journal*, Aug. 1851; CORNIL ET TRASBOT, *De la Mélanose*, 1868; VIRCHOW, *Tumours* (the various volumes of the *Veterinarian* contain numerous reports of individual cases of melanosis; some are of great interest).

6. *Myxomatodes*.—Sarcomata are prone to undergo mucoid changes in different parts of their substance; such a change may even affect an entire tumour. Partially degenerate sarcomata are described as myxomatodes.

Dr Creighton¹ has published two admirable examples of this peculiar form of tumour.

¹ This *Journal*, vol. xiv.

Both tumours were removed from dogs at the Brown Institution, London, 1875.

The first growth was situated immediately beneath the skin of the neck, a piece of the integument being removed with it. The interior was cystic, and contained a clear fluid, brownish in colour, and of mucous consistence. The entire growth was 3 inches in diameter, the cyst walls being in some places more than an inch in thickness. Elongated, narrow cystic spaces were found at several places in the cyst wall. The mass of the tumour was soft and almost gelatinous. The second case was removed from the hip, it lay close under the skin. It was not cystic, but its texture was mobile and fluctuating. It was definitely rounded, flattened on its lower surface, and was about 2 inches in diameter. The minute structure was the same in both tumours; that of mucous sarcoma or myxomatodes.

The cells were large, about three times the diameter of a leucocyte, and somewhat flattened on one or more sides. There was a central nucleus, and a wide zone of cell-substance, which is especially granular at the periphery.

The intermediate ground-substance in the cystic case was granular after the tumour had been preserved. In the case from the hip, the intercellular substance was made up of fibrils, or of thicker homogeneous bundles.

Many, perhaps most, of the sarcomata which occur in man and attain to any size, present in some part or other of their bulk patches of tissue undergoing this peculiar mucoid change. When speaking of round-celled sarcomata, it was stated that when they occur in dogs they commonly present a cystic interior, and there are strong reasons for believing that mucoid degenerations of these new growths occur with greater frequency in dogs than in any other animal. The cause at present is not very obvious.

7. *Alveolar Sarcomata*.—This peculiar variety of sarcomata very strongly resembles, in the histological features, the carcinomata. These tumours consist in the aggregation of cells into groups, separated by septa of fibrous tissue. The cells are of the round variety; they are usually of large size, and, according to some authors, it is possible to distinguish a delicate reticulum between the cells. It is in this particular form of tumour that the classification of new growths, based on histological grounds alone, fails, for it is impossible to be absolutely certain, from the microscopical details alone, whether we are dealing with a cancer or an alveolar sarcoma, so closely is the glandular type mimicked. Hence we are driven to ascertain its mode of

genesis, whether from connective tissue or epithelial multiplication. The accompanying illustration was taken from a specimen of this form of sarcoma (Plate XXIII. fig. 10), which grew immediately beneath the skin of the mamma of a bitch. For the opportunity of recording this case, and for the microscopic sections, I am indebted to Dr Heneage Gibbes.

The true relationship between alveolar sarcoma and medullary carcinoma is an interesting and important question. The tumours of the testis present us with very valuable material in this respect, and it is really a doubtful question as to whether we have reliable indications by which we can state positively that a given tumour of the testis is a sarcoma or carcinoma. Until some decisive investigation is made as to the origin of the epithelial lining of the seminiferous tubules, the question must remain *in statu quo*. I hope to make this question a subject for future study, but the custom of emasculating domestic animals adds great difficulty.

8. *Osteo-Sarcomata*.—An osteo-sarcoma is a variety of sarcoma in which the growth becomes calcified, or may even become converted into true bone. The primary seat of these growths is almost exclusively in connection with bone, arising either from the periosteum or the medulla. Examined microscopically they will be found composed in places of calcified tissue or imperfectly formed bone, containing in its trabecular meshwork round cells, spindle-shaped cells, or the giant-cells so characteristic of myeloid sarcomata. In Plate XXIII. fig. 6, an example of this variety of tumour is represented which grew from the leg of a rat. It is of considerable size, and contains all the variety of cells just enumerated, besides a considerable quantity of pigment scattered throughout the growth.

9. *Psammomata*.—This name psammoma has been applied to a curious form of tumour occasionally found attached to the membranes of the brain and spinal cord. The distinguishing features of these growths is the presence of a gritty substance, *acervulus cerebri* or brain sand, such as is normally found in the pineal gland; indeed, the structure of this appendage of the cerebrum may be taken as the physiological type of the psammoma. This sabulous matter consists of phosphate and carbonate of lime, with a little phosphate of magnesia and

ammonia, combined with animal matter. Besides the pineal gland, it may often be detected in the choroid plexuses, dura mater, arachnoid, and Pacchionian bodies.

Virchow distinguishes two varieties of psammomata.

(1) The sand occupies the interior of cavities, which are formed by fasciculi of fibrous tissue, in the form of compact cylinders or pyriform masses.

(2) In this variety the sand is diffused through the tumour in the form of minute, rounded, or elliptical corpuscles. These grains, when isolated, may show a concentric arrangement.

Virchow insists on the distinction of these gritty particles from corpora amylacea, by their structure, chemical characters, size, and hardness.

Although these growths are so exceedingly rare in the human subject, as for the most part to be regarded as pathological curiosities, yet they must occur with tolerable frequency in the horse, to judge from the number of reported cases to be found in the pages of the *Veterinarian*. The most frequent situation of these tumours in the horse is the choroid plexuses, in which situation they are usually symmetrical. They vary in size from a small pea to that of a hen's egg. Even when of large size they rarely cause any symptoms to indicate their presence, probably on account of their very slow growth, but occasionally they have been known to give rise to furious symptoms leading to the death of the animal.

The largest tumour I have found recorded, is one by Lassaigue in the *Ann. Chem. et Phar.*, lxii. 292. The mass as large as a hen's egg was found in the right lateral ventricle of an old horse; it weighed 14 drachms, and gave rise to no symptoms. It was composed of cholesterine, 58; membrane and albuminous matter, 39·5; and subphosphate of lime, 2·5.

The presence of cholesterine in tumours connected with the choroid plexuses is well attested.

In 1854 Leblanc made an interesting communication to the Imperial and Central Society of Veterinary Medicine, Paris, on the subject of tumours of the brain.¹ He referred to a case of enlargement of both choroid plexuses to fifteen times their normal size. Each mass contained a considerable quantity of small nacreous bodies known to be composed chiefly of cholesterine, which was arranged in the form of crystalline plates, like the leaves of a book; some phosphate of lime was also deposited in a crystalline form.

¹ Vide *Veterinarian*, 1855.

Pearly masses of cholesterine have also been detected in the tissue of the choroid plexus by M. Bouley, jun.

Leblanc believes this condition of the plexuses to be associated with an abundant accumulation of serous fluid in the ventricles, but on insufficient grounds.

Accumulations of cholesterine have been seen on the choroid plexus of the fourth ventricle of a mare, in the form of small globular-shaped masses, like beads on a string, each having the characteristic lustre of cholesterine. The animal was liable to sudden attacks of excitement, when standing in the stable as well as at work.

A very careful and exact account of these bodies is given by John Gamgee in the *Veterinarian*, 1852.

He shows most conclusively that cholesterine enters largely into their composition, as well as small spherical bodies, composed of phosphate of lime.

Gamgee also states that Dr Bennet describes the mode of formation of these bodies in the choroid plexuses in the following manner:—

“At first there seems to be deposited a quantity of mineral granules in round or oval patches, more or less large. As these become more numerous, a clear centre, composed of transparent homogeneous mineral substance may be seen, which gradually extends to the circumference, until the whole presents an uniform mass. They are in many respects very similar to the mineral concretions so common in the prostate gland.”

After comparing the descriptions of a large number of these curious tumours from the brains of horses, with tumours occurring in a corresponding situation in the ventricles of the brain of human beings, the only distinction that can be drawn between them is, that in the horse cholesterine and phosphate of lime are present, the former in considerable quantity, whereas in man phosphate and carbonate of lime make up the earthy matter, cholesterine being absent.

Adrenal-tumours.—A curious tumour, occupying the dorsal region of the abdomen, came under my observation in a marmot (*Cynomys ludovicianus*). The growth was in relation with the anterior end of the right kidney, and in shape as in situation corresponded exactly with an adrenal enormously enlarged; the left adrenal was normal in size and structure, the right being represented by the mass above described (*vide* Plate XXIII. fig. 7). The liver was occupied by numerous secondary nodules, which on section presented a curious mottled appearance (Plate XXIII. fig. 8.). There was one secondary nodule in the posterior end of the spleen.

When examined microscopically the tumour presented an arrangement of cells in columns, exactly recalling the histological details of the cortical substance of the adrenals, particularly the part known as the zona fasciculata, even to the peculiar brown pigmentation of some of the cells. After dissolving out the fat contained in the cells with ether, the structure became much more obvious (Plate XXIII. fig. 9). It was not until after some cautious deliberation that I became convinced that in this tumour one had to deal with tissue corresponding to adrenal tissue. In my hesitation I conferred with Mr F. Eve, of the Royal College of Surgeons, without suggesting anything as to the probable nature of the growth; he came to the conclusion that it was histologically of the nature of adrenal tissue.

TUMOURS CONTAINING EPIBLASTIC AND HYPOBLASTIC TISSUES.

EPITHELIAL TUMOURS.—The characteristic features of the tumours now to be considered is that, in addition to tissues mesoblastic in origin, they contain *epithelial elements*. They all consist of a framework or stroma of vascular connective tissue, in which the epithelial cells are embedded, the variety of tumour depending (1) upon the relation or proportion of the cell-elements to the stroma; (2) the shape of the cells composing the tumour; (3) the type of construction or *mimicry* of the tumour.

Some of this class of growths resemble, in their structure, glandular organs, and exhibit a very definite resemblance to particular glands. These tumours have been termed in consequence adenomata.

If the glandular type be imperfectly followed, so that we distinguish only clusters of epithelial cells produced in nests formed of fibrous tissue, the term carcinomata is applied to these morbid growths. The essential difference between an adenoma and a cancer is, that in the former the cells tend to clothe the walls of the alveoli in a regular way, leaving a central lumen, as in the acinus of a gland, whereas in the cancers no such lumen or orderly disposition of the cells can be detected; but they are all tumbled in confusion into the nests formed by the fibrous tissue. It must be borne in mind that sarcomata

sometimes mimic this alveolar arrangement. The distinction between an alveolar sarcoma and a carcinoma is that the cells in the latter are of epithelial origin. It must be admitted, however, that it is exceedingly difficult to distinguish between a cancer and an alveolar sarcoma, merely by the structural details.

Classification of Epithelial Tumours.

- | | |
|--------------------|------------------|
| (1) Adenomata. | (c) Scirrhus. |
| (2) Carcinomata. | (d) Colloid. |
| (a) Epitheliomata. | (3) Papillomata. |
| Squamous. | (a) Epidermal. |
| Cylindrical. | (b) Mucous. |
| (b) Medullary. | |

1. ADENOMATA.—Adenoma is the name given to a tumour whose histological details conform to the type of a secreting gland. Care is necessary to discriminate between an enlargement (hypertrophy) of a gland and a true glandular neoplasm, the distinction being this—the latter is impotent to produce the secretion normal to the gland, and is foreign to the tissue in which it is situated, notwithstanding the fact that it originated from pre-existing gland-structures and in the substance of glands, but microscopically they can be distinguished from the affected tissue.

These tumours may undergo secondary changes, such as fatty degeneration of the epithelium, caseation, and mucoid softening. Dilatation of the saccules and tubules may occur, leading to the formation of cysts which may attain considerable dimensions.

The mammary gland is frequently occupied by these tumours. They have been found in the bitch and in the cow.

When seated on the mucous membranes of the intestines they are frequently composed of convoluted tubules, and bear a striking resemblance to Lieberkuhn's follicles. Probably the majority of the tumours found growing from the colon of the horse are of this nature. They may attain a weight of 70 pounds.

Tumours of this character, growing from a free surface, exhibit a tendency to form masses projecting into the cavity of hollow organs; they are then familiarly known as mucous polypi.

Such masses have been described in connection with the vagina of the mare, cow, bitch, ewe, also in the nasal fossæ of horses.

One variety of ovarian tumour resembles in its structure the adenomata. In this situation they sometimes attain enormous dimensions. They have been reported in a mare fourteen years old to weigh upwards of 30 pounds, and to measure 37 inches in circumference.¹ In the cow they seem to be more frequent, and greatly exceed this weight; in the bitch an ovarian glandular tumour has been known to weigh 15 pounds, and in the ewe 7 pounds. In such an organ as the ovary, adenomata imperil life on account of the size they attain, but do not invade surrounding structures; but in the stomach intestines, and rectum they often assume malignant characters, reproducing themselves in other organs. In the nasal fossa they frequently recur after removal.

2. CARCINOMATA.—A carcinoma is usually defined as a growth characterised by epithelial multiplication, which is its essential and distinguishing feature. The cells are epithelial in their type, and are grouped together irregularly within alveoli formed of a more or less dense fibroid stroma, but there is no inter-cellular substance. The varieties of cancer are based mainly upon the form of the cells, the mode of infiltration, and the abundance and texture of the stroma.

(a) *Epitheliomata*.—Of this form there are two varieties—Squamous and Cylindrical—according to whether the cells of the growth are flat (squamous) or columnar (cylindrical); this will depend mainly upon the situation of the tumour.

So far as I have been able to ascertain from recorded cases of tumours in animals, and from observation, epithelioma is a rare form of morbid growth. Two undoubted cases have occurred in dogs, in both animals at the margin of the anus. The surface of the tumour was ulcerated, the edges raised and hard, and a foul, turbid liquid escaped from its free surface. Many other cases of tumours of this character have been reported, but as no microscopic examination was made, the nature of the growths is unknown.

In one carefully reported case epithelioma occurred in the

¹ *Veterinarian*, 4th series, vol. xv.; 4th series, vol. vi.

bladder of a horse sixteen years old. It had a nodulated appearance, and measured 5 inches in diameter. The muscular coat of the bladder had hypertrophied, and the fasciculi were strongly marked, except in the neighbourhood of the cancerous deposit, where they were lost. The histological details are carefully given in the original account of the case.¹

The sheath of the bull (prepuce) and the penis appear to be somewhat frequently affected with a morbid growth, which many veterinary authorities believe to be epithelioma. Many of the cases are nothing else than warts. Judging from specimens which have been preserved in spirit, the condition in a few cases strongly resembles this form of cancer, but it is impossible to speak definitely on this point, until an opportunity occurs of examining carefully hardened specimens. The disease often recurs after removal. Horses in India are liable to an affection named *Bursattee*, which is very prone to attack the mouth as well as other parts. Some veterinarians believe it to be epitheliomatous in its nature, but when carefully investigated it will no doubt turn out to be parasitic.

The remaining varieties of cancer insensibly blend with each other, the distinguishing features depending upon the proportion of fibrous stroma in any individual tumour.

1. *Medullary or Encephaloid Cancer*.—In this form the cells are very abundant, the stroma delicate and scanty, the tumour is soft, and often gives rise to the impression when manipulated of a cystic interior. The occurrence of this variety of cancer in animals is well attested; indeed, it seems to be the commonest form of cancer in them. One exceedingly frequent situation is the eyeball and orbit, where such growths attain enormous dimensions. A well reported case of this kind will be found in the *Veterinarian* (4th series, vol. iii. p. 431). A large encephaloid cancer involved the eyeball and optic nerve in a horse. The diagnosis was confirmed microscopically by Gairdner, Bennett, and Haldane in the Edinburgh University. Professor Axe,² the well-known veterinarian, in reporting on the histological details of a cancerous tumour weighing 13 ounces, removed from the orbit of a horse aged 12 years, states that such tumours are

¹ *Veterinarian*, 4th series, vol. xxviii.

² *Ibid.*, vol. xx.

very common in the eyes of horses and other domestic animals, oxen, dogs, and sheep. Guy's Hospital Museum contains a specimen of medullary cancer affecting the cornea and conjunctiva of a horse. The growth is of the size of a walnut; I have had an opportunity of examining it microscopically.

Carswell reported on a medullary cancer of the spleen of a horse which weighed 102 pounds.

The mammary gland in mammals as in man is liable to become the seat of this form of cancer. Dr Heneage Gibbes has furnished me with sections of this form of cancer, from the mammary gland of a bitch, in which the structure of medullary cancer was most perfectly shown.

It is well recognised that a form of new growth generally recognised as medullary cancer is prone to attack retained testes in man; the following cases¹ are interesting, inasmuch as they show that the same predisposition prevails in the lower animals :—

The first concerns an aged grey pony, a rig. At its death an immense lobulated tumour occupied the lumbar region, weighing 20 pounds. The left testis was retained in the abdominal cavity. It measured 8 inches in length, and was of corresponding breadth and thickness. Its surface was covered with small lobulated growths. On section the testis presents a various coloured surface, dark towards the centre, where there was some calcareous deposit. The epididymis was much enlarged and diseased like the testicle. The enlargement extended through the cord for a distance of 8 inches. The specimen was examined by Professor Axe, who pronounced it to be encephaloid. The large mass in the lumbar region being secondary to the disease in the testicle.

Encephaloid cancer has also been reported in a retained testicle of a dog.²

These cases show conclusively that cancer is a morbid growth not confined to man but affects domesticated animals as well. Former writers, Rayer, Rousseau, Tanchou, and others have mentioned the occurrence of cancer in animals, but the term is not used by them in that definite sense with which it is now employed. I am well within bounds in stating that there are not fifty examples of tumours described in animals where the detailed account of the histological nature of the tumour can be

¹ *Veterinarian*, 4th series, vol. xxv. p. 262.

² Medullary cancer of testis is placed here provisionally, *vide* the remarks under Alveolar Sarcoma, p. 456.

relied upon. The following cases occurring in wild animals will perhaps on this account be more valuable :—

Among interesting instances of carcinomata must be included one shown at the Pathological Society, London, February 1885, by Dr Goodhart. It was the brain of a baboon (*Anubis*), which had a large ragged looking tumour over the optic chiasma. The nerves and other parts of the brain appeared to be quite healthy. The base of the skull showed, by the eroded condition of the bone, that the tumour had occupied the pituitary fossa, and spread outwards in the adjacent part of the middle fossa. It evidently had its origin in the pituitary body. The tumour is composed of large epithelial-looking cells, arranged in an alveolar manner. This arrangement of cells, associated with the fact that the pituitary body arises from epiblast, justifies its position among the carcinomata.

The animal lived in the Zoological Gardens, London, and presented head symptoms some weeks before its death. The specimen is now in the museum of the College of Surgeons.

It is an interesting circumstance to know that even reptiles are liable to the inroads of cancer.

A python (*Python sebae*) which had lived in the Zoological Society's garden for fifteen years was found to be ailing, and as it grew worse it was deemed advisable to kill it. On making the *post-mortem* examination the viscera were found to be the seat of an enormous number of secondary growths. The liver measured 3 feet in length, and was studded with hard yellowish-white nodules, varying in size from a pea to that of a large walnut. The lung contained twenty similar nodules of the size of a pea. The kidneys had each a large mass of new growth at their posterior ends equalling in size a large walnut. The ovaries had several nodules of the size of an orange, some being rather smaller (Plate XXIII. figs. 11 and 12).

The nodules in all the organs were of a yellowish-white colour, exceedingly hard to the touch, and many on being cut into exuded a greenish coloured fluid. This was most obvious in the ovarian masses.

In histological details they conformed to medullary cancer, being made up of alveoli containing masses of irregular cells. The alveolar walls are exceedingly thin and in places difficult to distinguish. None of the growths were vascular, and the larger masses showed cavities, the result of disintegration of the morbid growths.

It was impossible to decide as to the original seat of the growth, but, taking into consideration the size of the ovarian tumours, and the relation of the blood stream to the other organs, I came to the conclusion that the ovaries may have been the starting-place of the mischief.

2. *Scirrhus Cancer*.—In this variety the cells are less numerous, the stroma very abundant, the tumour is firm and hard to the touch, creaks when cut with a knife, and on section presents the glistening appearance of a firm fibrous tumour. The only difference histologically between this and the preceding variety is the excessive proportion of fibrous stroma.

A morbid growth, corresponding to the above description, has not yet come under my notice in an animal; it may be due to accident, but it is certainly very curious that a growth so fearfully prevalent in the human female, should be so rare in the lower animals. It suggests facts for future meditation, and should urge those who have opportunities to investigate the matter.

3. *Colloid Cancer*.—This resembles scirrhus cancer in the abundance of its stroma, but, in the place of cells, its alveoli are filled with a gelatinous colloid material. This condition is probably brought about by the colloid degeneration of the cells.

The most striking example of colloid cancer that I have seen in animals occurred in the mammary gland of a bitch, the sections of which were placed at my disposal by Dr Heneage Gibbes. In this case it is possible to distinguish in the sections portions which correspond exactly to medullary cancer, and in other places every stage of colloid change, from a few drops in the middle of an alveolus, to large tracts of degenerated tissue. At the periphery of the tumour the histological details correspond in every particular with what would easily pass as good examples of scirrhus cancer.

PAPILLOMATA.—These tumours in their ultimate structure resemble an agglomeration of ordinary papillæ, and like them grow from cutaneous and mucous surfaces. In structural details they resemble exaggerated papillæ of the skin, and consist of a base of richly cellular connective tissue supporting

blood-vessels, the whole being overlaid by a covering of epithelium, the character of the cells varying with the situation of the growth. Those growing from skin have a hard epithelial investment, whilst those from mucous surfaces are softer in consistence. The individual papillæ may be single, but often possess secondary or tertiary papillæ.

Papillomata are of frequent occurrence in some animals. Favourite situations in sheep are the feet, immediately above the coronet and at the margin of the mouth. The museum of the College of Surgeons possesses a splendid specimen of papillomata in the head of a dog; the mouth, hard palate, tongue, lips, and cheeks are beset with these growths. The trachea had similar growths near its bifurcation.

There is also an œsophagus of an ox in the same collection, with the whole of its mucous surface covered with a growth of warts. This is by no means uncommon, and several cases are recorded in veterinary periodical literature (Plate XXIII. fig. 13).

The museum of the Veterinary College contains a very good example of this condition also in the œsophagus of an ox. It was observed by the butcher when the animal was killed; no symptoms were observed during the animal's life. They strongly resemble the villous-like processes which beset the mucous surface of the œsophagus in turtles.

This is the best place to notice a curious variety of cutaneous growth, which is occasionally found on the cornea. In man they are usually situated at the limbus conjunctivæ, partly on the cornea, or on the sclerotic. The surface of such growths is usually smooth, but they may be lobulated. These tumours are as a rule congenital, and almost stationary, increasing very slowly with the rest of the body.

In one case described by Wardrop¹ twelve long hairs grew from one of these patches, passed between the eyelids, and hung over the cheeks. These hairs did not appear until the patient's beard commenced to grow.

The following cases show that such growths are not confined to human beings:—

Dr Dobson published an account of one which grew on the eyeball of a mongrel bull-terrier.

¹ *Morbid Anatomy of the Eye.*

The patch of integument was triangular in outline, with its base corresponding to the outer margin of the cornea and the apex towards the outer canthus. The skin was clothed with hair exactly like that on the dog's back. The abnormal patch looked as though a piece of skin had been taken from the animal's back and grafted on the eyeball. The dog was full grown, but the testes were not in the scrotum.

In 1870 a sheep's eyeball was sent to the College of Surgeons, London, for preservation in the museum, which presents a similar condition. It is thus described by Dr Garson¹:—"The preparation shows at the outer canthus and superiorly a projection resembling a mole; it is of rounded form, measuring about 5 millimetres in diameter, situated along the edge of the cornea. From the top of this springs a lock of wool, some of the fibres of which are as long as 6 cm. The growth is of a brown colour, more deeply pigmented at some points than at others, so that it presents a mottled appearance (Plate XXIII. fig. 14).

The following case occurred in a greyhound puppy aged three months. On the ball of each eye, at the outer corner, there is a quantity of hair, which entirely covers the white of that part, and approaches quite up to the pupil (*Veterinarian*, vol. xxvi. p. 777).

Among this class of growths must be placed the following curious example contained in the museum of the Royal College of Surgeons. It is the head of a cock, with a large conical mass protruding from the external auditory meatus, of the size and shape shown on Plate XXIII. fig. 15. It seems to be made up of a mass of epidermal cells, and resembles the horn-like growths now and then seen in human beings, originating in sebaceous follicles or cysts.

Everard Home, in 1791, contributed an interesting paper to the *Phil. Trans.*, entitled "Observations on Certain Horny Excrescences of the Human Body." After referring to numerous well-marked cases of horny growth occurring in human beings, he describes the following case in a footnote:—

A sheep, about four years old, had a large horn, 3 feet long, growing on its flank. It had no connection with bone, and appeared only to be attached to the external skin. It dropped off in consequence of its weight having produced ulceration of the soft parts to which it adhered. On examining it there was a fleshy substance, several inches long, of a fibrous texture, filling up its cavity, on which the horn had been formed.

Hunter was well aware that these horns are nothing more than cuticular productions arising from a cyst, and Home refers to a case which grew from the tip of a sheep's ear, and shows the analogy these spurious horns bear to the horn of the rhinoceros, thus:—"The horn

¹ *Journal of Anat. and Phys.*, vol. xiv. p. 252.

of the rhinoceros is a cuticular appendage, similar to nails and other cuticular excrescences, being in no respect allied to horns but in the external appearance."

TERATOID TUMOURS.

The teratomata are a group of congenital tumours remarkable for the variety of the elements composing them. They may contain fibrous tissue, bone, cartilage, muscle, skin, hair, nerves, glands, or indeed any tissue. The most frequent situations for such tumours are the head, the sacral region, the neck, and the genital organs, ovary, and testis.

This class of tumours, both in man and the lower animals, has received a considerable amount of attention at the hands of such eminent teratologists as St Hilaire, Gurlt, Förster, Ahlfeld, and others, that there is no need for me to enter further into the question at present.

The forms of teratomata known as dermoid cysts, when occurring in the head, deserve a little notice, as they are often, when containing teeth, confounded with dentigerous cysts.

Dermoid cysts are a variety of teratomata whose inner surface has the same structure as normal skin, but they may occur in situations where skin is not normally found. The contents of these cysts are usually sebaceous matter, hair, teeth, and occasionally other tissues. If the cyst is of any size it is surrounded by a fibrous capsule.

Dermoid cysts containing teeth occur with especial frequency in the horse, the most frequent situation being the temporal region near the glenoid fossa. There are many instances recorded of the occurrence of these cysts on the petrous portion of the temporal and the sphenoid bone in the horse and ox. Cysts containing hair have been found embedded in the muscular substance of the tongue of an ox.

ÆTIOLOGY OF TUMOURS.

There are many points in this account of the comparative pathology of tumours, which are interesting in connection with that fascinating subject, the ætiology of new-formations. The theory of Cohnheim, which ascribes the origin of tumours to persistent germinal rudiments, is, of all hypotheses that have

been proposed, the one that has most to recommend it, if the name tumour be used in its most restricted sense.

The origin of true cysts from functionless ducts and tubules is a fact which no one can doubt; for example, the cystic dilatation of the tubules comprising the parovarium, paroophoron, par-epididymis, and duct of Gärtner in man and animals. In the last number of this *Journal* an endeavour was made to demonstrate the origin of other examples of cysts in frogs, toads, birds, &c., from rudimentary ducts. If, then, we receive without demur, the origin of cystic structures from functionless tubular organs, why should the origin of solid tumours from rudiments be doubted, especially if the existence of such untransformed tracts of tissues can be demonstrated unequivocally to be heteroplastic in their nature.

The existence of a piece of cartilage in the midst of the shaft of a long bone in a boy, aged 5 years, is cartilage in the wrong place, yet such was the case in the section of the lower end of the femur represented in fig. 23.

The existence of cartilage islands has now been known for some years, and Virchow showed that such untransformed pieces of cartilages may be regarded as tumour germs, and later in life, if circumstances be favourable, may actually develop into tumours—enchondromata. It is quite possible that osteomata may thus arise, for this latter variety must only be regarded as an advanced stage of development of an enchondroma.

A frequent spot for the existence of these belated rudiments, is that region of the skull, known as the asterion. It will be readily seen on reference to fig. 24, that a region of hyaline cartilage exists in the foetal skull posterior to the tympanic annulus. The figure was taken from the skull of a fœtus at about the fifth month, the cartilage in question being a remnant of the primordial chondro-cranium. As ossification



FIG. 23.—Rickety epiphysis of femur with a cartilage island.

proceeds, this tract of cartilage is invaded by the following centres, pro-otic, epi-otic, opisthotic, and pterotic, belonging to the periotic capsule; by the ex- and squamo-occipitals, and by the stylo- and tympano-hyal ossifications. Thus no less than eight independent ossific centres invade this cartilage, and come into more or less close relationship near the region asterion. In this scramble, little tracts of cartilage get locked in, and may often be seen in young skulls, from the fœtus up to puberty. Of all regions of the skull, the asterion is by far the most frequent seat of exostoses; this is true, not only of man, but of some animals, particularly horses.



FIG. 24.—Skull of a fœtus at the fifth month, showing the chondral condition of the region asterion.

In a short but interesting paper in this *Journal*, vol. xiii. p. 200, Professor Turner draws attention to some observations of Seligman, Welcker, Barnard Davis, and adds some of his own, calling attention to the fact that in certain deformed skulls described as Titicaca's, Huanaka's, and Aymara's, exostoses in the neighbourhood of the external auditory meatus existed. Also in skulls from the natives of the Marquesas Islands, and in deformed Peruvian skulls, these growths have been detected. More recently, Professor Turner has described similar exostoses in Sandwich Island, Chatham Island, and New Zealand Crania.¹ He is careful to point out that these exostoses are not race

¹ Report on Crania collected by H.M.S. Challenger, *Zool. Chall. Exp.*, pt. xxix., 1884.

peculiarities, as Professor Welcker was also aware, and this is borne out by the fact that in the Barnard Davis collection exostoses occurred in races widely separated. The late Mr Toynbee stated, that out of 1013 ears he dissected, 14 cases of bony outgrowths from the walls of the meatus were found. These facts seem to strongly support the view that exostoses in this region arise from the islands of cartilage so common in this situation.

If it be admitted that exostoses in relation with the external auditory meatus arise in this way, then the same origin applies to osseous tumours in relation with the jaws, orbits, nasal fossæ, pelvis, vertebral column, and long bones of the limbs. The fossæ of the skull were originally fashioned in cartilage, and untransformed tracts of this tissue may occasionally be detected, especially in young skulls.

In the long bones the origin of belated rudiments is rather to be looked for in connection with the epiphysial cartilages rather than the chondral tissue of the original shaft.

The heterogeneity of a piece of cartilage in the midst of a compact bone is a condition of things almost certain to attract attention, but in the case of muscle fibre, fibrous tissue, and the like to the naked eye the distinction is not so obvious, and as these tissues are always more or less mixed, the detection of such, as tumour-germs, in any organ, is open to much misinterpretation.

It must be remembered that all germs, even when they exist, do not develop into tumours. Three roads are open—(1) they may later in life undergo transformation into normal tissue; (2) they may remain quiescent throughout life, unless (3) irritation stimulate them into abnormal activity. As to what constitutes irritation in this sense nothing at present is definitely known.

There are certain forms of iritic cysts which support the notion of tumour-germs very strongly. Cysts of the iris are of two forms; hygromata which contain a watery fluid, the walls being composed of a basement membrane lined with a layer of tessellated epithelium. The other form simulates sebaceous cysts, and, like them, possesses thick walls and enclose epithelium and epithelial débris. It has often been observed by oculists, or oph-

thalmologists as they now prefer to call themselves, that these cysts often arise as sequelæ to an injury of the cornea. The probable explanation of their origin is, that during the injury some particles of epithelium are carried into the anterior chamber and engraft themselves on to the iris, and develop much in the same way that a fragment of epidermis placed on a granulating surface would engraft itself and give rise to new epidermis. Some ovarian cysts supply us with facts exactly analogous to this. Cases have been placed on record where papillary cysts of the ovary have from some cause (injury) ruptured, and their contents have been diffused far and wide throughout the peritoneal cavity; the various cell elements of the cyst thus diffused have engrafted themselves on the peritoneum and developed veritable new growths.

Who can gainsay that those rare cases of sebaceous cysts, occurring deep in the tissues of the neck, may not have had their origin in defective closure of the branchial clefts, which form such prominent features in the early embryonic history of every mammal that breathes. Those cysts, familiar as hydrocele of the neck, doubtless belong to the same category.

The sarcomata are an exceedingly difficult group to deal with. In the early stage of the general development of the embryo the connective tissues assume a gelatinous condition, it being only in the later stages that the definite forms of the various tissues are assumed,—fibrous tissue, cartilage, bone, and the like.

The sarcomata in their histological characters are modifications of immature connective tissue, such as so largely pervades the foetus, and the various forms of the sarcomata are to be regarded as immature conditions of foetal connective tissue, which persist as such, instead of advancing to a higher grade of development. Probably the round-celled sarcoma is the lower, and the spindle-celled the higher conditions of this tissue, for we know that spindle-celled growths exhibit great tendency to chondrify and even to ossify.

Tissue development and growth are at an acme in youth, gradually declining as life advances. In the same way sarcomatous growths are most frequent in youth; occur less frequently in middle life, and least often in senility.

The epithelial or glandular type of tumours present us with

some interesting features of tumour development, the type of this class of new-formation being glandular tissue which never attains a functional condition. If the development history of a gland be traced out, it will be found to commence by a down-growth of epithelium, from the epiblast or hypoblast, as the case may be, into the deeper layers of the mesoblastic tissues beneath. This stage is well shown in the accompanying figure, which represents a magnified view of a section carried through the thumb of a foetus at the fourth month. The epithelial down-growth and the mesoblastic elements disport themselves in various ways, and glandular organs of different types are built up, producing mucous, sweat, milk, sebum, or other secretions. If, later in life, irritation, local or otherwise, affect the tissue, abnormal epithelial growths may occur and rise above the general level, produce a wart, or, dipping into the subepithelial tissues as in the early stage of gland-formation, but failing sufficient formative energy, either from decline of vigour or general constitutional debility, the new tissue never develops functionally, runs riot, and originate tissues of low vitality—carcinomata. On Plate XXIII. fig. 16 is shown a section through a skin graft, placed on a granulating surface, which was left after removal of a congenital papilloma. It is interesting to note that the cells invade the tissue like the advancing border of an epithelioma.



FIG. 25. — Section through the distal end of the thumb of a fourth month foetus, showing developing sweat glands.

The ingrowths may occur in the neighbourhood of any glands, mucous, sebaceous, mammary, and others, as diverticula from the acini of existing glands, and according to the arrangement and variety of the cells and stroma, so we term them epithelioma, scirrhus, encephaloid, and the like.

There is no valid reason why these abnormal down-growths of epithelium as a result of irritation should not be considered as tumour-germs in the same sense as the little masses of cartilage lodged in the interior of a long bone.

The facts recorded in this paper lead to some conclusions of great interest; the most important may be summarised as follows:—

1. No tumours are peculiar to man; certain forms occur with greater frequency in him than in other animals, notably the cancers. This may depend on paucity of observations, but the conclusion is warranted by our present knowledge.

2. Sarcomata, fibromata, osteomata, and enchondromata are the most widely diffused of all growths; they occur in fish and all intermediate forms up to man. We have reliable evidence of the occurrence of osteomata in extinct forms; these growths constitute an ancient inheritance.

3. Fatty tumours are almost entirely confined to animals long domesticated,—the ox, horse, sheep, &c.

4. Odontomata are of frequent occurrence in mammals.

Finally, it is to be hoped that those who have opportunities of obtaining tumours in animals will record them in accessible places, taking care to supply also a detailed account of the structure, by neglecting which much valuable material has been lost to pathological science.

The writer will be very glad to receive examples of tumours in animals, either recent or preserved, in order to make our knowledge more complete on this important subject.

EXPLANATION OF PLATE XXIII.

Fig. 1. A variegated rat with a large fibrous tumour, measuring 3 inches in its longest diameter, growing in the cellular tissue of the neck, immediately below the integument. (College of Surgeons Museum.)

Fig. 2. The femur of a cat with a large exostosis growing from its shaft near the great trochanter. (Museum of Guy's Hospital.)

Fig. 3. Portion of the tail of a horse affected with melanotic sarcoma.

Fig. 4. A similar specimen more intensely pigmented. (The two specimens are in the Museum of the College of Surgeons.)

Fig. 5. Character of the cells in melanotic sarcoma of the horse. (After Cornil and Trasbot.)

Fig. 6. The leg of a rat with a large osteo-sarcoma developed upon it. It is represented one-third the natural size.

Fig. 7. The kidney of a marmot with the adrenal many times larger than normal.

Fig. 8. The liver of the same animal, showing numerous secondary deposits.

Fig. 9. Microscopic appearance of sections of the enlarged adrenal after the fat had been dissolved out by ether.

Fig. 10. Drawing of the microscopic appearance of an alveolar sarcoma, from the mamma of a bitch.

Fig. 11. Portion of the liver of a python, affected with secondary nodules of medullary cancer.

Fig. 12. Kidney of same python, showing a secondary nodule.

Fig. 13. Portion of the œsophagus of an ox, with papillomata on its mucous surface. (Museum of the College of Surgeons.)

Fig. 14. Eyeball of a sheep with a lock of wool growing from a cutaneous patch on the cornea. (Museum of the College of Surgeons.)

Fig. 15. Head of a cock with a large conical mass protruding from the external auditory meatus. It is made up of epidermal cells. (From the Museum of the College of Surgeons.)

Fig. 16. Section through a piece of skin engrafted on a granulating surface, to show the peculiar manner in which the epithelial cells invade the tissue, resembling in this respect an epithelioma.

ON THE HYOMANDIBULAR CLEFTS AND PSEUDO-BRANCHS OF LEPIDOSTEUS AND AMIA. By
Professor R. RAMSAY WRIGHT, Toronto. (PLATE XXIV.)

WHILE engaged in the study of series of sections through the heads of young specimens (5–6 cm.) of *Lepidosteus* and *Amia*, in connection with an investigation into the brains of American Ganoids, my attention was attracted to certain remains of the hyomandibular clefts, which, it is generally supposed, abort entirely in these genera. After writing a preliminary note on these structures (No. 1), I learned, in correspondence with Professor B. G. Wilder, that he had already, in 1878, made a communication "On a Remnant of the Spiracle in *Amia* and *Lepidosteus*" to the American Association for the Advancement of Science. He had been led to look for traces of the spiracle in these genera on account of its persistence, in a more or less complete state, in the other Ganoids. The short paper communicated by Professor Wilder remained unpublished, as he was prevented from pursuing the subject. It was accompanied by figures illustrating the relationships of the parts in the adult *Amia*; discussed the nature of the spiracles, and their persistence in a more or less complete form in Selachians, Ganoids, and the Teleost *Megalops*, and concluded that the spiracles of *Amia* open to the exterior in the young.

I take this opportunity of expressing my indebtedness to Professor Wilder for two live specimens of *Amia*, which enabled me to confirm by injection the description of the vessels on p. 494.

Attention was early attracted by Joh. Müller (No. 2, p. 107) to the fact that, with regard to the opercular gill, pseudobranch, and spiracle, the Ganoids exhibit every possible combination. He gives the following table of their occurrence:—

	Opercular gill.	Pseudobranch.	Spiracle.
1. <i>Acipenser</i> , . .	x	x	x
2. <i>Lepidosteus</i> , .	x	x	...
3. <i>Schaphirhynchops</i> ,	x	...	..
4. <i>Polyodon</i>, . .	...	x	x
5. <i>Polypterus</i>, . .	...	...	x

At that time he regarded *Amia* as a Clupeoid; but, as he states (p. 133) that it is destitute of a pseudobranch, it would have represented to him a sixth combination if included in the above table, there being no trace of an opercular gill like that of *Acipenser*, and spiracles being hitherto denied to the genus.

In speaking in future of the parts in question, I shall employ the term "hoyoidean demibranch" for the opercular gill, and reserve the term "spiracle" for the outer opening of the "spiracular" or "hyomandibular cleft." Following Sagemehl (No. 3, p. 113), I shall speak of any gill supplied with already aerated blood as a "pseudobranch," and distinguish where necessary between hoyoidean and mandibular pseudobranchs.

Such a distinction is rendered necessary by the conflicting views of morphologists on the homology of the pseudobranch of the Teleosts. By Müller it was regarded as the homologue of the mandibular pseudobranch of the Sturgeons and Selachians, the hoyoidean demibranch being supposed by him to disappear in the Teleosts (No. 4, p. 111). Gegenbaur, on the other hand, believes it to represent the hoyoidean demibranch, the mandibular pseudobranch having disappeared in the Teleosts along with the cleft to which it belongs (No. 5, p. 568). Gegenbaur's views have recently been further developed by Maurer (No. 6), while Dohrn (No. 7, p. 147, and No. 8, p. 321) defends Müller's interpretation. It cannot be doubted but that the condition of the parts in *Lepidosteus*, and especially *Amia*, when thoroughly elucidated, will definitely settle this question.

With the object of tracing the homologues of the hoyoidean demibranch, mandibular pseudobranch, and hyomandibular cleft in these genera, it appeared desirable to study a form in which

all three are characteristically present. I had no young sturgeons of a size suitable for microtomy, and consequently employed embryo *Musteli* of about 6 cm., which I received some years ago from Dr W. K. Brooks.

The points to which I specially directed my attention were the form of the hyomandibular cleft, and the distribution of nerves and vessels to the neighbouring parts. Any detailed description of the vessels has been rendered unnecessary by the publication of Dohrn's recent paper (No. 8) in which these are fully figured. One important modification has been attained in the stage studied by me, viz., that the blood flowing towards the *circulus cephalicus* is now derived not only from the hyoidean demibranch, but also from first branchial arch the efferent artery of which (*eb'*, Plate XXIV. fig. 1) is connected with the first aortic arch by a wide stem (*eo*), into which the small proportion of the blood aerated in the hyoidean demibranch falls, which has not been carried off by the afferent artery of the mandibular pseudobranch. A further modification consists in the fact that the thyroid is no longer supplied with blood from the afferent artery of the hyoidean demibranch, but from a branch of a vessel (*tha*, fig. 2) containing aerated blood, the radicles of which originate in the ventral end of the anterior demibranch of the first branchial arch, and the remainder of which runs upwards and outwards on the ventral surface of the hyoid arch, supplying the parts between it and the mandible, till it reaches the hyomandibulo-hyoid articulation, and probably anastomoses there with the afferent artery of the mandibular pseudobranch. From its course I conclude that this is the thyro-mandibular artery of Dohrn; if so, its newly-acquired origin from an efferent vessel of the first branchial arch is worthy of note. We shall find that it corresponds entirely in its course to a vessel which originates in the same way in *Lepidosteus*, and which is obviously the *art. hyoidea* or *hyo-opercularis* of the Teleosts.

The form of the hyomandibular cleft may be studied in figs. 2 and 3. A shallow depression behind the eye contains the somewhat narrow aperture of the spiracle, immediately within which the cleft dilates into its most capacious portion. Into this there project from the ventral and anterior wall the filaments of the mandibular pseudobranch, while from the dorsal wall a narrow

canal is continued upwards and inwards, which soon widens into an oblique slit extending forwards immediately underneath that portion of the auditory capsule which lodges the external semi-circular canal. From its relation to the capsule this may be termed the auditory diverticulum of the hyomandibular cleft.

Several other Selachian genera possess such auditory diverticula, as was first indicated by Job. Müller (No. 9, p. 276), who believed that they serve for the direct conduction of sound-waves to the cranial cartilage. In recalling this observation of Müller, Sagemahl remarks (No. 10, p. 211) as a noteworthy circumstance that the hyomandibular cleft of the Selachians—the homologue of the tympanic cavity and Eustachian tube of the higher vertebrates—should possess the same function as these structures.

The mode of development of the Eustachian tube in relation to the hyomandibular cleft has not been satisfactorily established in the Amphibia. In the higher vertebrates (*cf.* Hoffmann, No. 10a) it appears to be always developed from a diverticulum of the cleft—the *canalis tubo-tympanicus*—while the cleft itself aborts. The fact to be afterwards brought forward that the Ganoids as well as the Selachians possess a recess occupying a similar position relative to the cleft as does the *canalis tubo-tympanicus* of the higher forms, renders it very desirable to ascertain the condition in the Dipnoi and Amphibia, with the view of learning whether the diverticula are homologous.

The inner half of the hyomandibular cleft is considerably less capacious than the outer half, but it also possesses a diverticulum, the aperture of which is both mesad and cephalad of the aperture of the other. This anterior diverticulum has the same general forward direction as the auditory recess, but it does not approach the cranial cartilage. About the middle of its course its lumen becomes suddenly much constricted, and thereafter as suddenly dilated, so as to terminate in a cavity of oval form. While the rest of the hyomandibular cleft is lined by epithelium resembling that of the mouth, the oval cavity referred to possesses a modified epithelium, ciliated at least in part (fig. 4). Although my specimens do not admit of a thorough study of the elements in question, I cannot doubt but that they constitute a neuro-epithelium. In favour of this view is the height of the

epithelium, which on the median wall is as high as that of the *macula acustica sacculi*—44 μ .—while the lateral wall is clothed by a single layer of tall cylindrical cells half that height, and the ordinary epithelial lining of the cleft is not more than 13 μ . We shall find strictures of undoubted sensory character in the hyomandibular cleft of *Lepidosteus* and *Amia*, and shall return to this in *Mustelus apropos* of its nerve-supply.

There are only two nerves which it is necessary for us to consider in connection with the parts engaging our attention—the glosso-pharyngeus and the facialis. Each of these nerves conducts itself in the following manner (*cf.* van Wijhe, No. 11, p. 19):—After escaping from the cranial cavity, it divides into a dorsal and a ventral branch. The former is very slender, and is distributed to the overlying parts of the system of neuromastic¹ canals. The latter forks over the underlying visceral cleft, sending down a strong post-trematic branch, which courses along the anterior aspect of the visceral arch behind, while a slenderer præ-trematic branch goes to the posterior aspect of the preceding visceral arch, and is closely connected with a pharyngeal or palatine branch distributed to the mucous membrane of the roof of the mouth.

The glosso-pharyngeus arises from the medulla in advance of the plane represented in fig. 2, gains the interval between the *ductus canalis posterior* of the labyrinth and the sacculus, and escapes from the cranial cavity behind the sacculus. It immediately detaches its dorsal branch, and in the same plane the præ-trematic branch to the hyoidean demibranch.

Behind this point a palatine branch arises from the ganglion, which chiefly ends in the mucous membrane below the articulation of the hyomandibular with the cranium. Separated by another short interval is a second twig to the palate, and then the remainder of the nerve, the post-trematic branch, descends to supply the anterior demibranch of the first branchial arch.

After separation from the acusticus ganglion, the ganglion of the facialis enters the orbit, and there detaches from before backwards—

¹ I have proposed the term neuromast (*νευρον μαστος*) as a convenient English equivalent of the German "Nervenhügel." It may be employed for all of the sense-organs of that category, whatever their shape, and whether free or protected in sacs, grooves, or canals.

1. The stout palatine branch, which is destined for the mucous membrane medial to the palato-quadrate cartilage.
2. A dorsal branch, to be afterwards discussed.
3. Buccal and muscular branches.
4. Behind the orbit a few twigs, which run back to the filaments of the mandibular pseudobranch; and finally
5. The remainder of the nerve forks between the two diverticula of the hyomandibular cleft (fig. 3) into the præ- and post-trematic branches.

The distribution of the latter of these is familiar; the former is at this stage a branch of considerable size. It appears to end in the mucous membrane of the dorsal and anterior wall of the cleft, without there being any modification of the epithelium at the point in question. It is possible that this is the remains of the fusion between the still undivided nerve and the epithelium of the cleft described by van Wijhe (No. 11, p. 26).

The result of the apparently similar fusion between the dorsal branch and the epiblast is the development of a portion of the neuromastic tract. Whether the neuro-epithelium which I have described in the medial diverticulum of the cleft, and which receives some fibres from this præ-trematic branch, is to be regarded in the same light, I must leave undetermined, although, from the occurrence of a well-developed neuromast in the diverticulum of the hyomandibular cleft of *Lepidosteus* and *Amia*, I regard it as not improbable.

Froriep (No. 12, p. 35) finds that the facialis fuses with epiblastic epithelium in the neighbourhood of the hyomandibular cleft, and suggests that the resultant rudimentary sense-organ may be similar to the fusion with the epithelium of the gill-cleft described by van Wijhe. But the sense-organs to which I now call attention are undoubtedly hypoblastic in origin. As far as I am aware, this is the first instance recorded of sense-organs of this category developed from hypoblast, although "end buds" are common enough in the cavity of the mouth, as well as in the skin.

The dorsal branch of the seventh is chiefly distributed to the dorsal tracts of the system of neuromastic canals in front of the plane represented in fig. 2, but the most posterior twig detached from it escapes upwards from the orbit just in front of the post-

orbital process in a groove of which it lies. This twig is destined for the supply of the transverse commissure of the neuromastic system, which joins the canals of opposite sides in the plane of the opening of the endo-lymphatic ducts. This is the commissure (*d*) in Meckel's diagram (No. 13, pl. ii. fig. 9), which is consequently not homologous with the supratemporal commissure of Ganoids and Teleosts, as the latter is supplied by the vagus. I find no commissure of the neuromastic system further back than this, nor do I find any dorsal branches of the vagus, although such are described for *Hexanchus* by Gegenbaur (No. 14, p. 341), and for *Pristiurus* by van Wijhe (No. 11, p. 33), where they supply a supratemporal commissure. From the course of the backwardly directed dorsal twig of the seventh referred to, I conclude that it is the homologue of the *ramus oticus*, to be presently described in *Lepidosteus* and *Amia*. It has been probably described heretofore as a "parietal" branch of the superficial ophthalmic nerve, and probably grows backwards from the facial element of that nerve at a stage later than that described by Marshall and Spencer (No. 15, p. 491) and van Wijhe (No. 11, p. 26.)

Lepidosteus.

From the table (p. 477) it will be observed that Müller regarded *Lepidosteus* as being destitute of a spiracle, but as possessed of an opercular gill and mandibular pseudobranch. The two structures so interpreted by him are two series of gill-filaments, the more dorsal of which projects into the gill-chamber from the mucous membrane covering the hyomandibular, while the more ventral is situated lower down and further back on the gill-cover. In the most recent paper in which these structures are discussed (No. 16, p. 429), Balfour and Parker observe that "Müller's views have not usually been accepted, but it is the fashion to regard the whole of the gill as the hyoid gill divided into two parts." I have met with few references to justify this remark. Stannius adopts Müller's view (No. 17, p. 219), as does Gegenbaur (No. 5, p. 568), while the upper half is generally spoken of as a pseudobranch, without specifically referring it to its proper arch (of Günther, No. 18, viii. 328.) Balfour and Parker were unable to contribute anything to the further elucidation of this point, as their oldest larvæ (26 mm.) showed no

trace of gill-filaments in this region, although the hidden gills were well developed. From my specimens of twice that length, I have arrived at the conclusion that the hyoidean demibranch is divided into two parts, of which the lower retains its functional activity, while the upper is a hyoidean pseudobranch. My results are thus at variance with Müller's view, although, as will afterwards appear, the argument against that employed by Balfour and Parker is invalidated by the persistence of the hyomandibular cleft.

The following summary of Müller's account is from No. 2, p. 104 :—

"The opercular gill of *Lepidosteus* is of considerable size, and abuts at an acute angle with its upper end against the much smaller pseudobranch. Both organs, similar in outward appearance, as in the Sturgeons, are in contact without being connected, and at the point of contact their filaments incline in opposite directions. The bulbus arteriosus forms a long stem, as in the Sturgeon and Polypterus, the muscular wall of which suddenly ceases before the artery begins to divide, which it does into anterior and posterior portions. From the latter there arise two stems, on each side of which the anterior are the afferent branchial arteries of the second arches, while the posterior divide for the third and fourth arches. The anterior part of the truncus runs further forwards, gives off on either side the afferent arteries of the first branchial arches, and is continued as a slender unpaired stem in the middle line. This stem divides into the afferent arteries for the opercular gills, which therefore receive venous blood. But the pseudobranch receives only arterial blood, and that from the *ramus opercularis*, which supplies the bones and muscles of the gill-cover, and which reaches the inner aspect of the gill-cover by an aperture similar to that in the Teleosts. It is probably derived from the ventral end of the efferent artery of the first branchial arch, and it is further probable that, as in the Sturgeon, the pseudobranch is a *rete mirabile caroticum* for both eye and brain, and not only a *rete mirabile ophthalmicum* as in the Teleosts."

I find that in my specimens the branching of the truncus arteriosus corresponds exactly to Müller's description, and not to Hyrtl's (*vide* Stannius, No. 17, p. 240).

The *arteria hyoidea* also arises from the ventral end of the efferent artery of the first branchial arch, as suspected by Müller. It gains the lateral or anterior aspect of the hyoid arch, and then divides into an anterior lingual and posterior hyoid portion. The latter runs backwards and upwards along the outer border of the hyoid arch, till it reaches the interval between the epihyal and symplectic, where it accompanies the *r. hyoideo-mandibularis*, vii. It does not reach the inner aspect of the gill-cover, however, by an aperture similar to that in Teleosts, but anastomoses with a vessel coming thence through the interval between the hyomandibular and interhyal, the origin of which may be now described.

Müller does not discuss the fate of the blood which is aerated in the opercular gill. Its afferent artery (*ahg*, fig. 7), after running along the inner or posterior aspect of the hyoid arch, is distributed in the capillaries of the gill, whence the aerated blood is collected by an efferent artery (*ehg*, figs. 7 and 8), which curves forwards towards the outer aspect of the gill-cover, and anastomoses with the *art. hyoidea* in the manner described above, and as is indicated in Agassiz's diagram (No. 19, p. 485). From this anastomosis is developed the afferent artery of the hyoidean pseudobranch, which bends over the symplectic to reach the inner aspect of the gill-cover (*ahp*, figs. 7 and 8), running backwards to its distribution in the filaments of the pseudobranch. The efferent artery of the pseudobranch runs forwards in the roof of the mouth and falls into the internal carotid artery at the point indicated in fig. 5, having crossed towards that vessel *in front of* the hyomandibular cleft. A small branch is continued dorsad from the anastomosis which supplies the afferent artery of the pseudobranch; it anastomoses with a small branch of the carotid, escaping with the facial *behind* the hyomandibular cleft (figs. 5 and 8).

From the horizontal section (fig. 5) may be gathered the mode in which the blood-supply of the head is derived. At the point where the efferent artery of the first branchial arch bends round to form with its neighbour the anterior end of the dorsal aorta, a common carotid artery arises, which runs forwards in the roof of the mouth below the cranial cartilage (*ca*, figs. 7 and 8). After giving off the small branch already referred to,

which accompanies the facial nerve, the artery enters the interval between the para-sphenoid and cranial cartilage, and divides into three branches, of which that nearest the middle line continues forwards between the membrane, bone, and cartilage, while the two other larger stems, which may be termed external and internal carotids, penetrate into the cranial cavity. The former (external carotid) has only a short intracranial course; it enters the cranial cavity of the foramen in the cartilage through which the *ramus palatinus* escapes, associates itself with the ventral aspect of the Gasserian ganglion, but becomes almost immediately extracranial by the formation of the trigeminal foramen. In its forward course it gives off branches to the mandibular muscles and orbito-nasal region. The latter (internal carotid) remains in the interval between para-sphenoid and cartilage, accompanied by the *ramus palatinus*, till it is joined by the efferent artery of the hyoidean pseudobranch, shortly after which it enters the cranial cavity by the hypophysial fenestra, and without forming a *circulus cephalicus* divides into branches, one of which is destined for the brain, while the others escape into the orbit, the main branch accompanying the optic nerve to the eye.

It was chiefly from consideration of the blood-supply that Müller regarded the pseudobranch of *Lepidosteus* as the homologue of that of the Selachians, and it is obvious that the agreement is very close with the condition described in *Mustelus*. The pseudobranchs in both receive blood which has been aerated in the lower part of the hyoidean demibranch, and also from a vessel, the *art. hyoidea* or *hyo-opercularis* of Ganoids and Teleosts, which is derived from the ventral end of the efferent artery of the first branchial arch; also, the blood emerging from the pseudobranchs falls in each case into a stream directed forwards from the dorsal end of the efferent artery of the first branchial arch, and destined for the supply of the brain and the ball of the eye. In spite of this agreement, the explanation of which I am unable to furnish from my material, other morphological considerations of greater weight, to be presently adduced, appear to me to justify the conclusion that the pseudobranch of *Lepidosteus* is the upper part of the hyoidean demibranch. Perhaps younger stages, or the condition of the vessels in the *Starionidae*, may furnish the desired clue.

The condition of the parts in *Lepidosteus* proves that the *art. hyoidea* of the Teleosts is not the homologue of the hyoidean aortic arch, as is sometimes assumed (*cf.* Owen, No. 19, p. 485), for the two vessels coexist in that genus. As remarked above, its course agrees with that of the thyro-mandibular artery of Dohrn. It appears to me to be homo-dynamous with the nutritive or branchial arteries which spring from the succeeding efferent arteries, in the way this does from the first, and to owe its greater relative size in the Ganoids and Teleosts to the development of the gill-cover from the hyoid arch. The Selachians also possess similar nutritive vessels (*cf.* Dröschner, No. 20, p. 170), and it is very easy to understand why that for the hyoid arch should be larger than those for the succeeding arches, whereas it is difficult to reconcile Dohrn's account of the origin of the thyro-mandibular artery with the condition in the stage of *Mustelus* described above. It is difficult to conceive an aortic arch losing its connection with the truncus arteriosus, and becoming connected with the efferent vessel of the *second* arch behind it. However, the evidence recently adduced by Dohrn as to the existence of an independent hyomandibular arch, between the mandibular and hyoid, promises to upset those generally accepted views as to the morphology of the parts in question, on the lines of which the description of the parts of *Lepidosteus* and *Amia* here given is based.

The Hyomandibular Cleft in Lepidosteus.

Apart from the communication of Wilder referred to above, no reference is to be found to the persistence of the hyomandibular cleft in *Lepidosteus*. In his memoir on the development of the skull (No. 21), Prof. Parker has apparently overlooked the perforation of the cranial cartilage by a diverticulum of the cleft to be described, and, indeed, the early atrophy of the cleft is asserted in the following passage from Balfour and Parker's important paper, already cited (p. 426):—

"The pharyngeal region, immediately after it has become established, gives rise to a series of paired pouches. These may be called the branchial pouches, and are placed between the successive branchial arches. The first, or hyomandibular pouch,

placed between the mandibular and hyoid arches, has rather the character of a double layer of hypoblast than of a true pouch, though in parts a slight space is developed between its two walls. . . . It does not appear to undergo any further development, and, so far as we can make out, disappears shortly after the embryo is hatched, without acquiring an opening to the exterior.

"It is important to notice that this cleft, which in the cartilaginous Ganoids and *Polypterus* remains permanently open as the spiracle, is rudimentary even in the embryo of *Lepidosteus*."

Although the hyomandibular cleft possesses no external aperture equivalent to the spiracle of Selachians or Sturgeons, and probably is never open to the exterior, yet it persists in the adult animal in a very interesting and important manner. The condition admits of a direct comparison with the same cleft in *Polyodon*, as described by Bridge (No. 22, p. 697). In that genus, as well as in *Amia* and *Lepidosteus*, there is a well-marked groove on the roof of the otic cartilage, which with Sagemehl may be called the "temporal" groove. Into the anterior end of this groove, which is *f*-shaped in *Polyodon*, a canal opens, which terminates by a slit-like aperture on the infero-lateral face of the periotic capsule, between the articular groove for the hyomandibular, and the attachment of the metapterygoid ligament.

Bridge says further of this canal—"In the fresh specimen it was seen that the slit-like inferior opening was situated in the inner wall of the spiracular passage, and that the mucous membrane of the pharynx was continued through it into the canal, but the upper part of the latter, and the depression into which it opened above, as well as the *f*-shaped groove, were filled with connective tissue infiltrated with fat. It may, in fact, be said that the first visceral cleft splits into two canals, a large canal opening at the spiracle, and a smaller one which perforates the otic cartilage, and opens on the superior surface of the skull. The canal is quite external to the semicircular canals and vestibule, though it approaches nearest to the horizontal canal. The meaning of this spiracular diverticulum was, at first sight, not very clear. I was inclined to regard it as having some connection with the remarkable fenestration of the infero-lateral face of the periotic capsule which occurs in the very early stage of the

embryo Salmon, and which Parker has called the 'primordial fenestra ovalis' from its analogy to the fenestra ovalis of the abbranchiate vertebrata.

"But further consideration suggested to me that the diverticulum in question might be nothing more than a result of the rapid growth of the cartilage of the ear-sacs round the upper part of the first visceral cleft, so as to constrict it off from the rest of the cleft, which remains as the spiracular canal."

On examining a fresh Sturgeon's skull, I found a diverticulum of the spiracular passage precisely similar to, but relatively smaller than, that described in *Polyodon*, and, as in the latter, opening into a basin-shaped depression in the roof of the otic capsule. The inferior orifice was just in front of the hyomandibular, and behind the mandibular gill; the upper part of the canal was filled with fat.

If Bridge had been familiar with the auditory diverticula of the spiracular clefts in such Selachia as *Mustelus*, he would have recognised the similarity of the condition in these chondrosteous Ganoids. That the diverticula in the latter are surrounded by the otic cartilage is to be attributed to the longer articular surface necessary for the changed form of the hyomandibular. Sagemehl has called attention to this factor for the occlusion of the spiracles in Teleosts (No. 10, p. 213). It is obviously the same cause which is operative here.

The most important point in which *Lepidosteus* differs from *Polyodon* is in the relative size of the diverticulum of the cleft, and the outer part of the main canal. In *Polyodon* the latter is larger, and opens freely to the exterior; in *Lepidosteus* it has no such opening, and either terminates blindly underneath the cranial cartilage (*sp.* fig. 8), or is represented there by a knob of epithelium. But the diverticulum of the cleft is always well developed, and has constant relationships to the neighbouring parts. It is chiefly the relationship of the inner part of the cleft to the pseudobranch which induces me to believe that the latter belongs to the hyoid arch. What this is may be seen from figs. 5, 6, 7, 8.

On the ventral surface of the hyomandibular adductor muscle there is a groove in the roof of the mouth (fig. 8), into which there opens in front of the muscle (fig. 7) the persistent

hyomandibular cleft. The cleft itself is directed upwards, outwards, and slightly backwards, but it will readily be observed from fig. 5 that it is separated from the most anterior filaments of the pseudobranch by the whole thickness of the hyomandibular adductor muscles. Arrived at the ventral face of the cranial cartilage, the cleft divides into two canals, the termination of which has been described above, and parts of which are seen in figs. 6 and 8. The epithelium lining the cleft is the same as that in the rest of the mouth-cavity, except on the antero-median wall, where it gives place to a long patch of neuro-epithelium, as distinctly belonging to the category of neuromasts, as the dermal canal towards which the diverticulum extends (fig. 8). Both neuromasts are in fact supplied by a branch of the same nerve, the *ramus oticus*, which extends outwards towards these sensory structures through a special canal in the cranial cartilage (figs. 6 and 8). In fig. 9 I represent the portion of the section drawn in fig. 8, which contains both epiblastic and hypoblastic neuromasts; they agree entirely in the form of the sensory cells, the hairs of which in the latter are agglutinated into a sort of "cupula terminalis." The epiblastic neuromast is almost entirely protected by a neuromastic bone—the future squamosal. Whether the neuromast in the cleft is the remains of a coalescence of the ventral branch of the facial nerve with the epithelium of the cleft, as one would be inclined to suspect from van Wijhe's account of the development of the cranial nerves in Selachians, must be left for the future to decide.

In further confirmation of the fact that the pseudobranch belongs to the hyoid arch, is the distribution of the nerve which I shall now briefly consider. As in *Mustela* the glossopharyngeus escapes first into the auditory capsule, and makes its way out between the *lagena cochleæ* and the posterior semicircular canal (against the acoustic branch for the ampulla of which it lies in passing) before reaching its special canal in the cranial cartilage. On emerging through this it at once forms a *ganglion trunci*, which lies in front of the foramen and below the jugular vein. Slightly behind the foramen a slender dorsal branch is detached, while slightly in front of it is given off the post-trematic branch for the anterior series of filaments of the

first gill. The ganglion cells cease opposite the level of the dorsal attachment of the first epibranchial cartilage, and from that point the præ-trematic branch continues forwards in the same position below the jugular vein. Arrived at a point in the same plane as the facial foramen in the hyomandibular, it divides into two branches, one of which (pharyngeal) is distributed to the mucous membrane of the palate, while the lateral branch *ends* in the filaments of the hyoidean pseudobranch. The above agrees completely with van Wijhe's results (No. 23, p. 78), with the exception to be noted below that the *lower* half of the hyoidean demibranch is innervated by a branch of the facial.

Only those branches of the facio-trigeminal ganglionic complex concern us here, which may be regarded as belonging to the seventh nerve. There are three of these, each with an independent aperture in the cranial cartilage, viz., (1) the truncus hyoideo-mandibularis, (2) ramus oticus, (3) ramus palatinus. These are detached from the ganglion in the order mentioned from behind forwards, in such a manner that the first and third come from the ventral edge of the ganglion, while the second arises from its dorsal edge. With regard to the first and third I have nothing to add to van Wijhe's account, except that the hyoid branch of the former, after supplying the neuromastic tract in the properculum, attains the inner aspect of the gill-cover, round the anterior border of the hyomandibular, and is distributed to the filaments of the hyoidean gill. The *ramus palatinus* appears to me to belong more intimately to the seventh than to the fifth nerve, and to be homologous with the *r. palatinus*, vii. of *Mustelus*. Sagemehl (No. 10, p. 201) has criticised this homology on account of the intracranial origin of the one and the extracranial origin of the other. But it is only necessary to remember that the facial ganglion is intracranial in the one case and extracranial in the other, to account for the difference in their mode of origin.

The ramus oticus also belongs unquestionably to the seventh, and not to the fifth, with which it is associated by van Wijhe. If it be homologous with the most posterior of the dorsal twigs of the seventh in *Mustelus*, it has attained in the Ganoids a much greater independence and importance. It is frequently of

great size in the Teleosts, as I have elsewhere indicated (No. 23, p. 357). Van Wijhe was the first to describe this independent branch of the facio-trigeminal group, indicating its constant distribution to the neuromastic canal in the squamosal bone. He did not detect its presence in *Lepidosteus* (*loc. cit.*, p. 115), where, however, it is present as in the other Ganoids (figs. 6 and 8). I have now to recall the fact that the *r. oticus* in *Lepidosteus* and *Amia* is not only supplied to the neuromastic tract in the squamosal, but also to that in the hyomandibular cleft and its diverticulum. If the latter organ be the result, as I have suggested, of the coalescence of the ventral branch of the seventh with the epithelium of the gill-pouch, as the former is of the dorsal branch with the epiblast, then that part of the *r. oticus* which supplies the neuromast in the cleft must represent the præ-trematic branch of the seventh, described above (p. 490) as terminating in the mucous membrane of the anterior wall of the spiracular cleft in *Mustelus*, and in the neuro-epithelium of its medial diverticulum. The fact that, like the post-trematic branch, it has to escape through the cranial cartilage to its destination, is dependent upon the intracranial position of the facial ganglion, and partly, of course, on the surrounding of the diverticulum of the cleft by the cranial cartilage as already explained. According to the above suggestion, then, the seventh nerve in *Lepidosteus* exhibits all of the branches possessed by the glosso-pharyngeus—viz., (1) *r. dorsalis*, (2) *r. pharyngeus*, (3) *r. præ-trematicus*, (4) *r. post-trematicus*. Whether this scheme will be established by future study of the development of the nerves remains to be seen; but the mere existence of a hyomandibular cleft would seem to argue for that of a *r. præ-trematicus*, vii.

It has been noted above that the lower part of the hyoidean demibranch is innervated by the hyoidean branch of the seventh. I would attribute this to the interruption of the vascular arch connecting the upper and lower parts of the hyoidean demibranch.

Amia.

It will only be necessary to dwell on those points in which *Amia* differs from *Lepidosteus*. It is generally described as being

destitute of a pseudobranch, the only reference to the existence of that organ I have found being by Sagemehl (No. 3, p. 113), who says:—"Bekanntlich besitzt *Amia* eine gut ausgebildete opercular pseudobranchie." So also no mention of any trace of the hyomandibular cleft is to be found in the literature treating of *Amia*. In his paper on the skull of *Amia* (No. 22), which preceded that on *Polyodon*, Bridge overlooks the perforation of the cranial cartilage by the diverticula of the hyomandibular clefts, which are common to both genera. On the other hand, Sagemehl (No. 10, p. 200) correctly describes the perforation of the cranial cartilage, but fails to interpret its nature. He says:—

"The ossification of the post-frontal does not extend through the whole thickness of the lateral wall of the chondrocranium, but is everywhere separated from the cranial cavity by cartilage. At the surface of contact between bone and cartilage lies a canal, which begins on the lower border of the bone on the lateral surface of the skull, and opens above in the interior end of the temporal groove. As far as I could ascertain, it contains vessels destined for the soft parts of the temporal groove. The canal has no further morphological significance, and I have merely referred to it for the sake of completeness."

It is the more surprising that the persistence of the spiracular cleft has escaped Sagemehl, as he devotes some space further on (p. 213) to the consideration of rudiments of the cleft in Teleosts, comparing such with the condition in *Polypterus*, and attributing the occlusion of the dorsal part of the cleft to the change in shape of the hyomandibular and its facet. There can be no doubt but that the above is the correct explanation of the condition in Teleosts; it is only to be noted that in the Ganoids, which possess a diverticulum of the cleft, this is not occluded, but surrounded in the course of the forward extension of the hyomandibular facet, so that the cranial cartilage comes to be perforated by the diverticulum in the same way that the hyomandibular is perforated by the facial nerve.

Before describing the vessels of the head in *Amia*, I shall briefly indicate wherein the pseudobranch and hyomandibular cleft in that genus differ from the corresponding parts in *Lepidosteus*.

Unlike that of *Lepidosteus*, the pseudobranch of *Amia* is

concealed, and resembles in many respects the "glandular" pseudobranch of *Esox*. In *Amia*, however, the separate compartment of the gill-chamber in which the pseudobranch lies—the pseudobranchial canal, as I shall call it (fig. 12)—retains a free communication with the gill-chamber by a slit-like aperture situated on each side immediately in front of the dorsal end of the first branchial arch (fig. 11.) The margins of the slit are toothed, and the teeth give rise to a minute cement bone on either side of the slit. No such aperture exists in *Esox*, but something similar is probably to be observed in those genera (*Salmo*, *Caranx*) where the pseudobranch is partly concealed and partly free (No. 4, p. 105). If figs 11 and 12 be compared with Maurer's figures (No. 6, pl. xii.) it is obvious that *Esox* passes through a stage of development which is persistent in *Amia*. It is further evident that the pseudo-branchial canal has been formed by the concrescence of the lips of such a groove as exists in *Lepidosteus*, the formerly free gill-filaments having been turned into the interior of the resulting canal. There can hardly be a doubt but that *Amia* passes through the stage which is persistent in *Lepidosteus*.

When I first observed in *Amia* the slit-like apertures referred to, I supposed, as did Wilder, that they were the oral apertures of the spiracular clefts, and jumped to the conclusion that the contained pseudobranchs, so evidently homologous with the pseudobranchs of Teleosts, must be also homologous with the pseudobranchs of Selachians and Sturgeons, as maintained by Müller and Dohrn. But Maurer's account of the development of the pseudobranch in *Esox* furnishes the connecting link between the condition in the adults of *Lepidosteus* and *Amia*, and I soon detected the true relationship of the hyomandibular cleft to the pseudobranchial canal in the latter genus.

In front of the foramen for the facialis there opens into the pseudobranchial canal a tube lined with the same epithelium, which extends forward and upward towards the interval between the hyomandibular and the sphenotic cartilage. Arrived there, it penetrates the otic cartilage in front of the hyomandibular facet, and ends cæcally in the loose tissue in the temporal groove. This tube is evidently equivalent to the ventral moiety of the hyomandibular cleft in *Lepidosteus* *plus* its diverticulum; there

appears to be no representative of that portion of the canal which tends towards the outside of the cranial cartilage in *Lepidosteus*. What has been said above with regard to the neuro-epithelium in the cleft and its nervous supply in *Lepidosteus* applies equally well to *Amia* (fig. 12). The *ramus palatinus* is relatively larger than in that genus, and divides into two branches, as noted by van Wijhe, the matter of which remains with the carotid in the interval between the para-sphenoid and cranial cartilage. Also the glosso-pharyngeus is similarly distributed, its pharyngeal branch being supplied to the mucous membrane of the roof of the mouth mesad of the pseudo-branchial canal, while the præ-trematic branch ends in the pseudobranch, and in the pad of connective tissue surrounding it (fig. 11).

It only remains to describe the arrangement of the vessels of the head. An important approximation to the Teleosts is exhibited by *Amia* in that there is no trace of an efferent branch from the ventral arterial trunk to the hyoidean arch. Even the *art. hyoidea*, so well developed generally in Teleosts and in *Lepidosteus*, is very small, and does little more than supply blood to the extremely large thyroid and certain other structures on the ventral aspect. The blood for the nutrition of the operculum and the opercular and mandibular muscles is derived from the dorsal ends of the efferent branchial arteries and from the carotids.

The dorsal aorta in *Amia* is chiefly formed by the union of the first and second efferent branchial arteries on each side, the third pair unite to form a coeliaco-mesenteric axis, while the fourth pair (the fifth aortic arches of the embryo) are distributed entirely to the air-bladder. *Amia* appears to furnish in this respect valuable evidence as to the complete homology of the air-bladder and lung, which has recently been questioned by Albrecht. Although its glottis is dorsal, the blood-supply is exactly the same as in *Polypterus*, where the glottis is ventral. In the face of what we know of the anatomy and conditions of life in the osseous Ganoids, the Dipnoi, and perenni-branchiate Amphibians, it can hardly be doubted that the air-bladder is completely homologous with the lung, and the only question that arises is as to the cause of the change in position of the glottis. Sagemehl appears to have contributed to the solution of

this problem by suggesting that the hydrostatic function of the air-bladder, and the dorsal position of its duct, are acquired, and not primitive.

Considerable difference is also to be observed in *Amia* when compared with *Leipdosteus* as to the disposition of the carotid vessels. From the point where the first efferent branchial artery bends round to join that of the other side, two vessels are given off, one of which is slightly dorsal of the other. The former accompanies the facialis in its outward course, sending important opercular and hyomandibular branches with it. A large branch also penetrates the brain case by the facial foramen, and, after giving off branches to the membranes and the auditory labyrinth, accompanies the Gasserian ganglion on its dorsal aspect, and escapes through the trigeminal foramen into the orbit, for the supply of some of the parts in which and of the nasal region it is destined. The ventral stem (*ca*, fig. 10) courses forwards in the roof of the mouth (fig. 11), but soon bifurcates into a lateral or external branch, which gets into the cranial cavity through the carotid foramen, and a medial or internal branch, which continues forwards between the para-sphenoid and the cranial cartilage. The former, during a short course within the cranium, lies on the ventral aspect of the Gasserian ganglion, but soon escapes with the trigeminus, the branches of which it accompanies (*ma*, fig. 10). Immediately on its escape it gives off the afferent artery for the hyoidean pseudobranch, which courses backwards on the dorsal aspect of the pseudobranch (*ahp*, fig. 12).

The efferent artery of the pseudobranch is found on the medio-ventral aspect of that organ (*eph*, fig. 12), it moves towards the internal carotid, but never unites with it, reaching the orbit by the canal for the ocular muscles, and penetrating the sclerotic to give rise to the dorsal part of the choroid gland. No *circulus cephalicus* is formed by the internal carotids, each of which continues forwards between the para-sphenoid and cranial cartilage till the hypophysial fenestra is reached, through which it passes into the cranial cavity, and, after giving branches to the membranes, eventually runs out along with the optic nerve to terminate in the ventral part of the choroid gland.

Sagemehl asserts the absence of a choroid gland in *Amia* (No. 3, p. 116), whereas the presence of a large one was already

known to Franque (No. 25, p. 9), and may easily be confirmed. The coexistence of this organ with a distinct and persistent hyomandibular cleft situated at a considerable distance behind the eye, appears to be quite unreconcilable with Hoffmann's account of the development of the choroid gland in *Salmo*, according to which that rete mirabile is the mandibular pseudobranch, and the matrix in which its capillaries are imbedded the modified epithelium of the spiracular cleft (No. 26, p. 77). Hoffmann's view has already been criticised by Dohrn (No. 7, p. 147).

In respect of the vascular supply of the choroid gland, *Amia* is very different from the Teleosts, but it appears to me desirable to withhold comment on this and other points connected with the vascular system of the genera investigated till further data are furnished by the study of younger stages.

In the following paragraphs are incorporated some of the more important results and suggestions to be found in the preceding pages:—

1. The hyoidean demibranch of *Lepidosteus* is divided into two parts, the lower functional, the upper (or pseudobranch) non-respiratory. The præ-trematic branch of the glosso-pharyngeus is distributed only to the latter.

2. In front of the pseudobranch is the persistent hyomandibular cleft, which has no external aperture (spiracle), but possesses a diverticulum recalling the auditory diverticulum of the same cleft in *Mustelus*. Unlike that, however, it is surrounded by the cranial cartilage as in *Polyodon*.

3. The cleft and diverticulum contain a long free neuromast (nervenhügel) supplied by a distinct branch of the *r. oticus* vii. It is possible that this sense-organ (represented also in *Mustelus*) is developed from the fusion of the *r. ventralis*, vii. with the epithelium of the hyomandibular pouch, in the same way that the neuromasts in the skin result from the fusion of the dorsal branches with the epiblast.

4. The condition in *Amia* is similar as far as the cleft, its diverticulum, and their nervous supply is concerned; but the cleft does not open directly into the mouth cavity only indirectly through a canal which lodges the hyoidean pseudobranch.

5. The occurrence of the diverticula referred to in the forms,

suggests an explanation for the *canalis tubo-tympanicus* of the embryos of higher forms.

6. The resemblance of the pseudobranch of *Esox* to that of *Ania* indicates that the pseudobranch of the Teleosts belongs to the hyoid and not to the mandibular arch.

7. The choroid gland of *Amia* has nothing to do with the hyomandibular cleft.

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EXPLANATION OF PLATE XXIV.

Lettering Employed.

<i>Add.</i> Adductor mandibulæ.	<i>Ep.</i> Epencephalon (region of cerebellum).
<i>Add, hmd.</i> Adductor hyomandibularia.	<i>G.</i> Gills.
<i>ad.</i> Anterior diverticulum of hyomandibular cleft.	<i>GI.</i> Ganglion interpeduncularæ.
<i>ade.</i> Aperture of endo-lymphatic duct.	<i>hps.</i> Hyoidean pseudobranch.
<i>ahg.</i> Afferent artery of hyoidean gill.	<i>Hmd.</i> Hyomandibular.
<i>ahp.</i> Afferent artery of hyoidean pseudobranch.	<i>Hy, a.</i> Hyoidean artery.
<i>al.</i> Auditory labyrinth.	<i>Hyp.</i> Hypophysis.
<i>amp.</i> Afferent artery of mandibular pseudobranch.	<i>ic.</i> Internal carotid.
<i>ao¹, ao².</i> First and second aortic arches.	<i>chy.</i> Interhyal.
<i>aud.</i> Auditory diverticulum of hyomandibular cleft.	<i>If.</i> Infundibulum.
<i>b.</i> Arterial branches for the brain.	<i>lms.</i> Levator maxillæ superioris.
<i>bhy.</i> Basi-hyal.	<i>Li.</i> Lobus inferior.
<i>bpg.</i> Basi-ptyergoid process.	<i>Lt.</i> Lamina terminalis.
<i>Cmd.</i> Coraco-mandibularis muscle.	<i>m.a.</i> Mandibular artery.
<i>Chy.</i> Coraco-hyoid.	<i>md.</i> Mandible.
<i>ca.</i> Carotid artery.	<i>mps.</i> Mandibular pseudobranch.
<i>c, a.</i> Commissura anterior.	<i>Mes.</i> Mesencephalon.
<i>cc.</i> Circulus cephalicus.	<i>met.</i> Metencephalon.
<i>chy.</i> Cerato-hyal.	<i>nc.</i> Neuromastic canal.
<i>co.</i> Commissure between aortic arches.	<i>nm.</i> Nictitating muscle.
<i>da.</i> Dorsal aorta.	<i>op.</i> Artery accompanying optic nerve.
<i>de.</i> Endo-lymphatic duct.	<i>orb.</i> Artery for orbit.
<i>Eb.</i> Efferent branchial arteries.	<i>Op.</i> Gill cover.
<i>ec.</i> External carotid.	<i>op.a.</i> Opercular artery.
<i>ehg.</i> Efferent artery of hyoidean gill.	<i>psc.</i> Posterior semicircular canal.
<i>ehp.</i> Efferent artery of hyoidean pseudobranch.	<i>Pr.</i> Prosencephalon.
<i>ehy.</i> Epihyal.	<i>q.</i> Quadrate.
<i>emp.</i> Efferent artery of mandibular pseudobranch.	<i>Rh.</i> Rhinencephalon.
<i>esc.</i> External semicircular canal.	<i>R.ot.</i> Ramus oticus, vii.
	<i>s.</i> Sacculus.
	<i>sc.</i> Semicircular canal.
	<i>sp.</i> Hyomandibular cleft.
	<i>sp'.</i> Diverticulum of cleft.
	<i>Sc.</i> Sclerotic.
	<i>tha.</i> Thyroidean artery.
	<i>thm.</i> Thymus.
	<i>thy.</i> Thyroid.
	<i>Th.</i> Thalamencephalon.
	<i>vj.</i> Vena jugularis.

The Roman numerals designate the cranial nerves.

Fig. 1. Diagram of dorsal part of arterial circulation in embryo *Mustelus*.

Fig. 2. Frontal section *Mustelus* through hyomandibular cleft.

Fig. 3. Part of section from the same series a little in front of above.

Fig. 4. Neuro-epithelium of diverticulum from a section still further forwards.

Fig. 5. Part of horizontal section through head of young *Lepidosteus* at the level of the base of the skull.

Fig. 6. Similar section from higher plane—that of the jugular vein.¹

Fig. 7. Frontal section of *Lepidosteus* of same age through hyomandibular cleft.

Fig. 8. Section from same series further back.

Fig. 9. Part of the above enlarged.

Fig. 10. Diagram of the dorsal part of the arterial circulation in *Amia*.

Fig. 11. Frontal section of head of young *Amia* through¹ opening of pseudobranchial canal.

Fig. 12. Section from same series further forwards.

¹ Limit between Prosencephalon and Thalamencephalon.

THE ANATOMY OF SPINA BIFIDA. BY Professor HUMPHRY.
(*Delivered as a Museum-Lecture in the University of Cambridge,
and taken, with a few Alterations and Additions, from the
"Lancet," March 25, 1885.*)

GENTLEMEN,—Finding considerable difference of opinion among surgeons respecting the anatomy of spina bifida, and especially, at which I was surprised, respecting the usual relations of the spinal cord and the spinal nerves to the sac, I have recently examined the specimens of this affection in most of the pathological collections of London, as well as some recent specimens which have been kindly submitted to me by Dr Goodhart and Mr Stewart. The chief points are, however, sufficiently demonstrated in the specimens before you, most of which were dissected and placed in the museum of the University by myself a good many years ago.

The name "spina bifida" is derived from one, and that not the most important, feature of the affection—viz., the separation or divergence, and in some instances the dwarfing, of the vertebral arches. This is associated with, and probably caused by, the protrusion from the vertebral canal of a sac containing a thin colourless fluid situated in the middle line, and of variable size. The affection is most common in the sacral, or the lumbo-sacral, region. The sac is more or less covered by skin, rarely altogether, but commonly to some extent of its circumference; the middle part being usually covered, rather formed, by a thin, translucent, bluish-red, more or less vascular, membrane; though in some instances this middle part has the appearance of a cicatrix. The thin, translucent, or cicatricial middle part, sometimes called the "Umbilicus," is continuous with the surrounding skin, the line of demarcation between the two being pretty clearly defined. The sac is commonly circular in outline, and its upper and lower borders afford some criterion of the extent in the spinal column to which the vertebral arches are deflected and the vertebral canal is opened. Still, the sac not unfrequently overlaps the unaffected arches above and below, and it usually overlies and extends beyond the everted arches at the sides. Dissection in most instances shows the spinal cord turning beneath the lowest entire vertebral arch—that is, the arch immediately above the spina bifida—and passing into some part of the wall of the sac. In some cases the cord runs, free, through the upper part of the sac to its middle, where the wall is composed of the thin membrane just mentioned. In other instances, immediately upon reaching the sac, the cord is blended with the wall of the sac, and requires a little dissection for its demonstration. The nerves, traced from the sacral, or the lumbar, intervertebral foramina, do not form a cauda equina in the usual manner, but are directed transversely, or nearly so, towards the same membranous part of the sac as the spinal cord; and, like the spinal cord, they are, in some instances, seen, in their course to this

part, lying free in the sac, whereas in others they lie, in their whole length, in the wall of the sac. In a third set of cases they present intermediate conditions, being partially free in the sac and partially embedded in its wall; or they are more or less united together by membranous bands which may be regarded as derivatives from the inner layer of the wall of the sac; and it is probable that the compartments, and even the cysts, occasionally found in connection with spina bifida sacs, may be thus produced. Thus, both cord and nerves pass to the sac, being stretched or lengthened in proportion to the size of the sac; and they are more or less blended with the thin membranous hinder part of it. In this specimen—at the lumbar and upper sacral region—the cord is seen entering the sac, traversing the upper part of its wall, blended with the hinder thin part, and then reappearing at the lower part, where something of a cauda equina is formed by the junction of the nerves of the two sides with the cord, and the median filament extends onwards towards the coccyx. The cord therefore in this case may be traced, and the anterior spinal artery is visible upon its surface, along the whole of the interior of the back of the sac, and from the sac into the sacrum; and the several lumbar nerves, from the two sides, pass on the wall of the sac to the cord. There was hydrocephalus in this case; and the central spinal canal, which communicated above with the distended cerebral ventricles, is dilated down to the spina bifida.

The nerve-roots and their ganglia in cases of spina bifida are not infrequently situated within the vertebral canal; and in some of the specimens before you, two or three adjacent ganglia are seen to be approximated and even joined together, and contained in one sheath of dura mater. This approximation and fusion are probably a result of the traction exerted upon the nerves in their passage upon the wall of the sac.¹

The cavity of the spina bifida, which, as we have seen, is, in some cases, traversed by nerves and partitioned by membranous septa, looks, in many specimens, as if it were continuous with the arachnoid sac, and as if it were lined by the arachnoid membrane. In some this is actually the case. It is so in the dorsi-lumbar specimen I have just shown you. The sac of the spina bifida is here formed by a dilatation of the anterior part of the spinal arachnoid cavity, the posterior part of that cavity, the part behind the nerve roots, being obliterated, or not having been formed. But a careful and close examination shows, in some at least, perhaps in most of those in the sacral or sacro-lumbar region, that this is not the case. The parietal and visceral surfaces of the arachnoid in the spinal canal, near to the sac or at its orifice, may be seen to be adherent; or the epithelial lining is reflected from the one to the other, so that the arachnoid membrane is not traceable into the spina bifida, and the spinal arachnoid cavity is shut off from the cavity of the spina bifida. The sac of the spina bifida accordingly appears to be formed in the subarachnoid space, and the lining of the

¹ This fusion of the ganglia was pointed out by Dr Fisher Downing, Professor of Medicine in this University (*London and Ed. Phil. Mag.*, vol. x. 516, 1837).

sac, as well as the coverings of the cord and of the nerves, and the more or less complete membranous septa, where these exist, must in that case be formed by the subarachnoid, or pia mater, tissue. It is not always easy to determine, even on dissection, whether the sac of the spina bifida is thus separate from the arachnoid cavity; but where it is so the fluid in the sac, and, in like manner, any fluid injected into the sac will not readily pass into and along the arachnoid cavity of the spinal canal and the skull, though it may permeate the thin membrane which forms the wall of the sac, and so reach the arachnoid cavity or the loose subarachnoid tissue of the cord, and thus extend along the cord to the brain.

The specimen of lumbo-sacral spina bifida which I have here, entrusted to me by Dr Goodhart, and which has been recently dissected for me by Dr Anningson, shows well many points of the anatomy of this malformation. The sac is of about the size of an orange, with the usual cicatricial tissue at the middle of its wall and with skin over the circumference. The skin and fat were easily removed near the spine, but are adherent to the subjacent layers of the sac near the middle, and ultimately blend with them in the cicatricial tissue. A tough structure, apparently the lateral halves of the interspinous ligament cleft like the spinous processes, was found, beneath the skin and fat, on the sides of the sac. It was connected laterally with the recurved and shortened vertebral arches and spinous processes. The dura mater of the cord expands over the sac, forming a thick covering pierced by the spinal nerves at the sides and blended with the other structures at the border of the cicatricial tissue. Beneath the dura mater is a double layer—visceral or spinal, and peripheral or subdural—of the posterior arachnoid (the arachnoid, that is, behind the nerve roots and the ligamentum denticulatum). These layers, though in close contact, were easily separated, the posterior arachnoid cavity being thus displayed. Like the other components of the sac, they are adherent and blended in the cicatricial tissue, and they are also closely adherent at the junction of the spina bifida with the spinal canal—at the level, that is, of the lowest complete vertebral arch; so that the posterior arachnoid cavity of the sac (in the wall of the sac) is quite shut off from the posterior arachnoid cavity of the rest of the spine. The visceral and peripheral surfaces of the anterior arachnoid (the arachnoid that is in front of the spinal nerves and the ligamentum denticulatum) were non-adherent; and the anterior arachnoid cavity was quite free along the whole length of the vertebral canal, including the spina bifida. The cavity of the sac is formed altogether in the anterior subarachnoid space, is entirely lined by subarachnoid or pia mater tissue, and is partially divided by imperfect septa of that tissue, projected into it by the spinal cord and nerves. A thick nerve-bundle, consisting of the spinal cord, with surrounding lumbar and upper sacral nerves, and forming, as it were, a retroverted cauda equina, turns beneath the last vertebral arch, leaving the bodies of the vertebrae, the anterior dura mater, and the anterior arachnoid. Thus, invested with pia mater or subarachnoid tissue only, it runs for a short space free in

the sac to the cicatricial tissue of the hinder wall of the sac; here the component cord and nerves, with their investing pia mater, are lost in the cicatricial tissue. The spinal nerves pass from the intervertebral foramina in regular order and pierce the dura mater separately all the way down from the head to the coccyx. The lower lumbar nerves having entered the dura mater, are, as we have seen, directed downwards, accompanying the cord to the back of the sac. The upper two sacral nerves, piercing the wall of the sac, take a more transverse course to the same point; and their ganglia, like those of the lumbar nerves, are outside the cavity of the arachnoid, and invested with sheaths of the dura mater. The nerve roots of the lower sacral nerves also pierce the dura mater, then run between the arachnoid layers in the wall of the sac—that is, in the posterior arachnoid cavity of the wall of the sac,—and so reach the cicatricial tissue; and the ganglia of their posterior roots lie in this posterior arachnoid cavity. Thus the wall of the sac is formed by the dura mater, the arachnoid, and the outer layers of the pia mater, together with the spinal cord and nerves; and the cavity of the sac is formed in the anterior subarachnoid tissue, and is lined, probably, by the endothelium of that tissue. Along the fore part of the vertebral canal the three coats, with the anterior arachnoid cavity, are undisturbed, and retain their normal relations with the bodies of the vertebræ, except that, as just said, the cavity is formed in the anterior subarachnoid, or pia mater, tissue, and a layer of that tissue is therefore expanded over the cavity; whereas at the hinder part of the vertebral canal, the three coats with the posterior arachnoid cavity, together with the nerves and the spinal cord, are stretched out to form the bulging wall of the sac, are more or less adherent to one another, and are all, as well as the cutaneous coverings, lost in the cicatricial tissue of the hindmost part of the sac. This specimen may be taken as illustrating the usual anatomy of a spina bifida, an accumulation of fluid in a cavity formed in the anterior subarachnoid or pia mater, with all the structures posterior to it—namely, subarachnoid tissue, spinal cord and nerves, posterior arachnoid membrane and cavity, dura mater, vertebral arches, subcutaneous and cutaneous tissues—stretched over it, and more or less imperfectly formed.

It is evident from the above anatomical considerations that the failure of development upon which spina bifida depends must occur at an early period of fetal life, in most instances before the spinal cord has been segmented from the epiblastic, or epithelial, layer of the embryo from which it is developed. It accordingly remains adherent to that external epiblastic covering; the imperfectly developed tissues of the cord and of the nerves passing to it, together with this covering, form the membranous wall of the sac; and the various structures which should be produced between the cord and the epiblast are to a greater or less extent abortive. The failure may even take place, it is believed by some usually to do so, before the central spinal canal has been closed; or the recently closed canal may give way and be re-opened by fluid accumulating in its interior; and in such case the

median posterior exposed surface of the sac must correspond with the epiblastic tissue which should have formed the epithelial lining of the central canal.¹ This often cannot easily be determined, for the central canal becomes occluded where the cord joins the membranous wall of the sac, in the lower regions of the vertebral column at any rate; and its precise relations to the sac cannot therefore be made out. It was so in the specimen we have just seen, when there were hydrocephalus and dilatation of the central canal down to the spina bifida. The canal in this case could easily be traced down to the spina bifida, but no further; and it was impossible to say positively whether the structure which represented it was continued into the cord lining the sac of the spina bifida, or whether it was continued upon the external surface of the sac, though the appearances are in favour of the former supposition.

Associated with the failure of segmentation and development of the several structures between the cord and the epiblast is the accumulation of fluid, or dropsy, by the pressure of which the sac is formed, the vertebral arches are recurved or stunted, the nerves and the spinal cord are elongated, and the tumour is produced. It is possible that the dropsical condition, due perhaps to something of an inflammatory process, may be the prime agent, and that by its pressure it has prevented the segmentation of the tissues from the epiblast, as well as induced the other changes mentioned; or the dropsy may be due to a want of resistance consequent on the non-segmentation and arrested development of those tissues—that is to say, it may be cause or effect. The balance of opinion and of probability is perhaps in favour of the former view. Further, when several vertebræ above the sacrum are affected, the fore part of the spine, composed of the bodies of the vertebræ and the intervertebral substances, being unsupported by the vertebral arches and articulating processes, which are abortive or deflected, may bend backwards or forwards. In this specimen, in the loins, it is bent backwards; in this specimen, in the neck, it is bent forwards, so that the chin rests on the sternum; and in this third example, also in the neck, it is bent backwards, so that the occiput lies on the back. These several defects in the vertebral column, including the open state of the vertebral canal with the separation, eversion, or stunting of the vertebral arches, are all consequences of the arrested development and the imperfect segmentation and imperfect formation of the various structures in the median line, and of the dropsical accumulation associated with them. The greater frequency of this failure and of the presence of spina bifida in the lower—the sacral and lumbo-sacral—parts of the spine, is probably owing to the fact that the closing of the primitive furrow, which is a little dilated at this part, and other developmental phenomena take place here rather later than in the upper regions; and they are therefore more likely to be interfered with or to be imperfect in this situation. A trace of this imperfection in the otherwise well-formed body is often

¹ See Contribution to the Study of Spina Bifida by Professor Cleland, *Journal of Anatomy and Physiology*, vol. xvii. p. 257.

to be seen in the smallness or incompleteness of the arch of the upper sacral vertebra, and also in the dimple in the skin over the coccyx.

I have thus described to you the anatomy of spina bifida, as it usually occurs in the sacral or the lumbo-sacral region; and you will have noted that the accumulation of fluid is usually in the subarachnoid space in front of the spinal cord, that the cord and the nerves are stretched backwards and outwards upon the sac, and are there confluent, together with the arachnoid, pia mater, and dura mater, or their representatives, in the thin membrane which forms the hindmost part of the wall of the sac. Moreover, it is to be remarked that the cord, being unsegmented from this thin membrane, and therefore fixed at this spot, and so fixed from a very early period of foetal life, does not undergo that shifting in relation to the vertebral canal which ordinarily takes place during the later periods of foetal life, and which is due to a greater proportionate growth of the vertebræ as compared with that of the cord. Hence the spinal cord, instead of terminating, as it does in the normal state, in the upper lumbar region, extends through the lumbar region into the wall of the sac, and may, in some instances, be traced beyond it to the lower part of the sacrum; and, as a sequence, the sacral and lumbar nerves pass transversely towards the cord in the sac, instead of ascending obliquely and forming a cauda equina; indeed, not unfrequently, as in a specimen I have shown you, the nerves traversing the spinal foramina just above the spina bifida take the reverse of their usual course and pass downwards, rather are dragged downwards, to the sac to join the cord. This, I say, is the usual disposition as demonstrated by much the larger number of specimens. In some cases, however, when the failure has occurred at a later period of foetal life, the segmentation and the formative development of parts have taken place to a greater extent; and the skin, with its epithelium and the subcutaneous tissue, may have been formed in a natural manner all over the sac. This is the most frequent in the neck. In some, as in this lumbo-sacral specimen before shown you, the neural axis is more separated than in the other cases—that is to say, it is less completely fused with the wall of the sac, and forms a distinct cord or band attached along the whole of the inner surface of the hinder wall of the sac. It may be, too, that in a few cases the segmentation and formation of the cord have been still more complete, so that it has become fully separated from the cutaneous and other tissues, and retains its normal place along the bodies of the vertebræ, and the dropsy, with the sac formed by it, is upon the hinder aspect of the cord. The cord would then not pass into the sac, at least would not pass along, and would not be attached to, the hinder bulging wall of the sac. This would constitute a “hydro-meningocele” or “hydro-rachis externa” *posterior*, in contradistinction to a “hydro-rachis externa” *anterior* in which the cord and nerves enter the sac, and blend with its wall; and both these are to be distinguished from a “hydro-myelocoele” or “hydro-rachis interna,” in which the fluid accumulates in the central spinal canal. Possibly this is so—that the fluid is behind the cord—in a specimen in the museum of St Bartholomew’s Hospital. The

specimen is a small spina bifida at the lower part of the sacrum, and the median filament of the cord and the nerves seem to be at the fore part of the sac; but further dissection is necessary to make the anatomy clear. In the College of Surgeons' museum is a specimen from an infant who died three days after the application of a ligature to a cervical spina bifida. The narrow peduncle of the sac passes through between the sixth and seventh cervical spinous processes, which are almost fully developed, and nearly meet in the middle line. The cavity of the sac appears, from the direction of a bristle placed in it, to communicate with the hinder part of the arachnoid cavity, and the cord possibly is not in the least degree implicated, and passes free along the hinder surface of the bodies of the vertebræ. But further dissection is required to make sure of this. It may be, as in an apparently similar case represented in Förster's *Missbildungen*, that the affection consists in a dilatation of the central spinal canal, and that a thin dilated sheet of the hinder part of the cord is prolonged into the wall of the sac—that is to say, it may be an example of “*hydrorachis interna*.”¹ This can only be determined, if in such a specimen it can be determined at all, by removing the dura mater, and making a careful examination of the parts. Whether the sac in this case was covered by skin or not cannot be seen. In cases of cervical spina bifida, occasionally met with, in which the sac has a narrow neck, and is covered by skin, the disposition is probably similar to that in the specimen just referred to. Like it, such cases furnish examples of the slightest degree of the malformation; and the examination of a larger number of specimens of the kind may enable us to judge what inference, as to the disposition of the cord and its relations to the sac, may be drawn from the presence of a covering of skin over the sac—whether, that is to say, the segmentation and development which have produced skin over the surface are associated with a corresponding segmentation and development of the cord sufficient to set it, with its pia mater and arachnoid, free from the sac, or so far free as to allow it to maintain its proper place in contact with the bodies of the vertebræ.

The fluid, as I have already said, appears commonly to be in the subarachnoid space in front of the cord; and the sac must in such cases, I conclude, be lined by an endothelium developed from that of the subarachnoid lymph spaces. In some instances the fluid is in the arachnoid cavity in front of the cord, and then the sac is lined by the endothelium of the arachnoid. In *hydrorachis interna*, where the sac is formed by a dilatation of the central spinal canal, the epithelial lining of the sac will be continuous with that of the central canal. The fluid may be, though this rarely is so, in the subarachnoid

¹ That is the case in a well-preserved and well-dissected specimen in the Musée Dupuytren in Paris. There is hydrocephalus and a spina bifida sac at the seventh dorsal vertebra. The spinal cord is normal above and below this point. At this point it is bent a little backwards towards the sac, and the hinder part of it is connected with, apparently expanded over, the sac. Some of the nerve fibres, those apparently from the posterior roots, have been exposed by dissection in the wall of the sac; and it is stated that the cavity of the sac is continuous with the canal of the cord.

space, or in the arachnoid cavity *behind* the cord. In these last cases the cord would occupy its normal position upon the bodies of the vertebræ, and the nerves would also have their normal position; whereas in the cases in which the fluid, whether arachnoidal or subarachnoidal, is in *front*, the cord and nerves are separated from the bodies of the vertebræ, and are applied upon and coherent to, or blended with, the wall of the sac. The dura mater is in all instances expanded upon the sac, and traceable to the same extent as the skin, becoming like it, and at about the same place, lost in the homogeneous membrane of the hinder part of the sac. Though I admit that the fluid may be behind the cord, the cord retaining its normal position, I must say that I have not been able to satisfy myself that this was the condition in any one of the many specimens I have examined. In every one, unless the one presently to be mentioned be an exception, in which the anatomy was clear, the cord, or some part of it, and usually the nerves, passed into the sac, and was united with the wall of the sac.

In those cases where the vertebral arches are more extensively deficient, and which are often associated with deficiency of the vault of the skull and with more or less deficiency of the brain, the vertebral canal is usually covered only by a thin membrane, and the spinal cord, with the several superadjacent tissues, is absent or represented by that membrane into which the spinal nerves pass and are lost. In the specimen, however, which I now show you this is not the case. The foetus is acranial and with spina bifida along the whole spine; the neck is bent sharply forward, so that the back of the head is in contact with the dorsal part of the spine. The cerebral mass is quite rudimentary; and the axial cord, of considerable thickness, passes directly backwards from the floor of the skull, bridging over the concavity of the neck, upon the dorsal vertebræ, and is continued upon the bodies of the vertebræ along the whole length of the lower dorsal, the lumbar, and the sacral portions of the spine. The nerves join it in regular sequence; but in the neck they are crowded together, and the lower cervical ganglia on each side are blended into one mass invested by a common capsule of dura mater. In the upper part of the cord the central spinal canal is wide and open, forming a continuation of the fourth ventricle. It gradually diminishes to the lower dorsal region, where it is closed in as usual; and below this the cord tapers into the median filament, which is continued to the coccyx. The specimen when it came into my hands, many years ago, was in its present condition; and to what extent the spinal central canal was dilated in the upper part, how it was covered in, what kind of covering existed over the spina bifida, and what was the cause of the eversion of the vertebral arches could not be ascertained. All that we can see is that the vertebral arches, without evident diminution of size, are thrown outwards and forwards, the vertebral canal is wide open in its whole length, and the spinal column is bent sharply forwards in the cervical region, and backwards in the dorsal region. The cord and the nerves lie on the bodies of the vertebræ in the sacral, lumbar, and

dorsal regions, and pass, straight over the concavity of the cervical curve, from the dorsal region to the skull; and in this part where it bridges over the curve the central spinal canal is dilated. It is a remarkable case, and it appears to constitute an exception to the rule of the cord being closely connected with the hinder wall of a spina bifida, and to the ordinary manner of formation of spina bifida.

I say nothing about other exceptional varieties of spina bifida, such, for instance, as where there is cleavage of the bodies of the vertebrae, or bony or cartilaginous growths from them into the vertebral canal, and other malformations. I have directed your attention chiefly to the more ordinary forms of spina bifida, the anatomy of which has acquired increased importance from the reintroduction of the treatment of the abnormality by injection. With reference to this treatment, you will understand that it is better to introduce the needle, not in the mesial line, especially in the upper part, where the cord is almost certain to be connected with the wall of the sac, but on one side. Further, you will perceive that the separateness of the cavity of the sac from the cavity of the spinal arachnoid, in most instances, is some security against the direct passage of the injected fluid into the latter cavity, and that the advantage of Morton's fluid, as an injection, probably depends upon the addition of glycerine to the iodine and iodide of potassium lessening the liability to the diffusion of those irritating substances through the delicate lining of the sac into the surrounding subarachnoid tissue.

NOTES OF SOME VARIATIONS OF THE SHOULDER-MUSCLES. By W. B. RANSOM, B.A., *Trinity College, Cambridge.*

IN the left arm of a strong male subject examined this session in the dissecting room of Cambridge University, an unusual number of muscular abnormalities was observed, some of which seemed worthy of record. The most remarkable peculiarity was a slender cylindrical *cervico-humeralis* muscle stretching across the shoulder above the nerves of the brachial plexus. Arising by three tendinous slips from the root of the transverse process of the seventh cervical vertebra on its anterior surface, this muscle passed transversely outwards above the brachial plexus, to the sheath of which it was closely connected by fascia, to be inserted by a tendon into the small tuberosity of the humerus in conjunction with the tendon of the subscapularis. This arrangement, so far as I am aware, has not hitherto been noticed, the nearest approach to it being the *cervico-costo-humeralis*, described by Gruber¹ as a complex muscular band arising from the oblique process of the sixth cervical vertebra and from the end of the first rib, and passing between the latissimus dorsi and subscapularis to the humerus. But the chief interest of this muscle, which may be called *cervico-humeralis*,

¹ *Mem. de l'Acad. Imp. de St Petersburg*, 1860.

would seem to be its relations of homology to the muscles of the lower limb. Corresponding to the subscapularis of the upper extremity, we find in the lower the muscular mass forming gluteus medius and minimus; and it is by no means a rare variety to find more or less fused with one of these muscles the muscle normally distinguished as pyriformis. Professor Macalister¹ has described the latter as fused with gluteus medius inseparately, except at the point of exit of the superior gluteal vessels and nerve, and has also seen its insertion inseparately tied to that of the gluteus minimus.

The pyriformis in this latter case is related to the gluteus minimus almost exactly as the cervico-humeralis to the subscapularis, and there thus seems fair ground for considering this new cervico-humeral muscle as homologous with the pyriformis, and as an intrusion into the upper limb of the hypaxial system of muscles.

Some further peculiarities occurred in connection with an axillary arch from the latissimus dorsi and with the pectoralis major.

The clavicular origin of the pectoralis major extended over two-thirds of the bone, and was quite separate from the sternal.

At the lower edge of the sternal portion were two partially separate slips arising from the fifth costal cartilage and the aponeurosis of the external oblique. Along the edge of the lower slip ran a long vein to the third part of the axillary vein.

The lower slip of the pectoralis major passed nearly parallel to the rest of the muscle, to be inserted, partly into the fascia of the axilla, partly into the sheath of the axillary arch of the latissimus dorsi, at a point about an inch and a half from its origin, and by its tension produced a curvature of the arch, the most convex part of which was at this point.

The upper slip was inserted, together with the axillary arch, into the deep fascia of the arm over the coracobrachialis. This common insertion took place by a tendinous band which stretched for nearly three inches down the fascia on the inside of the arm, and by a fan-shaped aponeurosis above, which was continued into that of the pectoralis minor, into the semi-vagina of the joint, and into the coraco-acromial ligament.

There was thus present in this region an unusually large combination of variations hitherto noticed separately.

KARL BARDELEBEN. "Das intermedium tarsi beim Menschen und Säugethieren," *Sitz. der Jenaischen Gesellsch. f. Medicin u. Naturw.*, 1st March, 27th April, 8th June, 1883. "Zur Entwicklung der Fusswurzel," *idem*, 6th February 1885. "Zur Morphologie der Hand, und Fuss-Skelets," *idem*, 15th May 1885.

In the above communications to the Philosophical Society of Jena, Professor K. Bardeleben has from time to time published his views on the homology of the tarsal and carpal bones, and on the presence

¹ A Descriptive Catalogue of Muscular Anomalies in Human Anatomy, *Trans. Roy. Irish Acad.*, 1872.

of a 6th, or, as he prefers to call it, a 0th digit, both in the hand and foot. He considers the accessory or secondary astragalus, occasionally met with in the human tarsus, specimens of which were described by F. J. Shepherd and by W. Turner in vol. xvii. of this *Journal*, as examples of a distinct os intermedium tarsi. He says that a well-developed separate os intermedium tarsi exists normally in the majority of the Marsupials, in which it varies in size. It is connected to the tibia, fibula, and astragalus either directly or through the medium of a simple or double meniscus. In Monotremes and some Edentates the astragalus is incompletely separated into two parts. He regards this os intermedium tarsi as homologous with the carpal semilunar, and he calls it the *os trigonum*, the astragalus of the higher mammals being composed of this os trigonum, fused with the general mass of the astragalus. The os trigonum is, in the second month of the human embryo, an independent cartilage, which, later on, blends with the astragalus. He has discovered that the navicular (scaphoid) element of the tarsus possesses, in addition to its chief mass of cartilage in the human embryo at the second month, a second smaller cartilage in the region of the tuberosity of the scaphoid. Owing to this discovery he no longer agrees with the homologies of the carpus and tarsus, which, on the authority of Gegenbaur, have so long been accepted, and he suggests instead the following schema:—

CARPALIA.		TARSALIA.	
Scaphoid.	{ scaphoid proper...radiale, tibiale....	cartilage of tuber-	} scaphoid.
	{ centrale of Rosen-	osity of.....	
Semilunar.....	berg.....centrale (2).....	chief part of	} astragalus of higher mammals.
	.....intermedium (1).....	os trigonum.....	
Cuneiform	centrale (1).....	talus s.s.	
	(or intermedium (2))		
Pisiform.....	.....ulnare, fibulare....	calcaneus.	

He has once seen the tarsal scaphoid with an inner ossicle in a youth, aged 15, which represented the separate cartilage of the tuberosity of that bone; and in almost a third of adult scaphoids traces of a suture were apparent around this tuberosity.

Bardeleben holds that the rudiment of a toe lying internal or on the tibial side of the hallux occurs as a tarsal or metatarsal 0, of a præhallux in Monotremes, American Marsupials, some Edentates, Carnivora, Rodents, Insectivora, and Apes. The rudiment of the præhallux articulates only with the endo-cuneiform in Marsupials, Carnivora, and Insectivora; with the endo-cuneiform or navicular in Edentates and Rodents; with both bones in *Paradocurus*; between endo-cuneiform and 1st metatarsal in Apes. The rudiment of a 6th or 0 finger, a carpal or metacarpal 0 of the præpollex, is only indicated in adult Marsupials; on the other hand, it is possessed by some Edentates, Lemurs, Rodents, Carnivora, Insectivores, Bats, and Apes. It is found in Lemurs and Insectivora on the trapezium; in Rodents and Carnivora between the scaphoid and 1st metacarpal; and in Apes between the trapezium and scaphoid. In *Centetes madagascariensis* there are two distinct centralia in the carpus.

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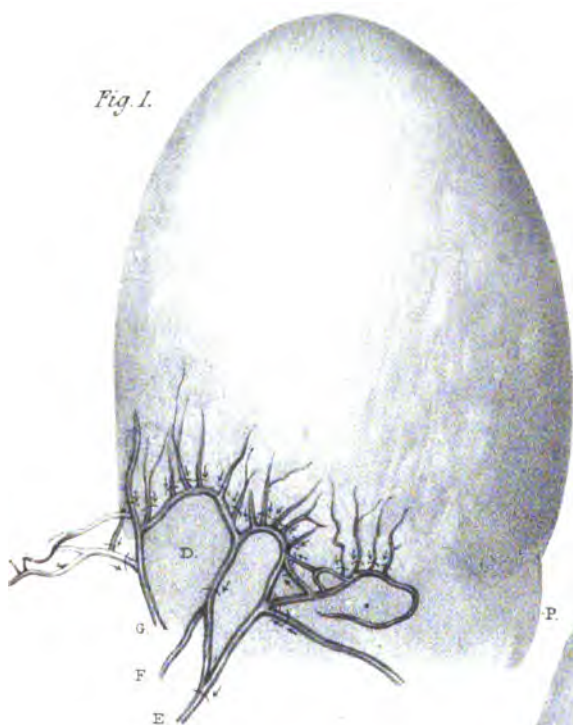


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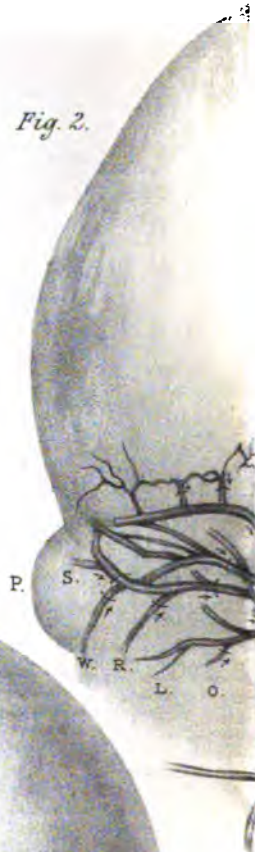


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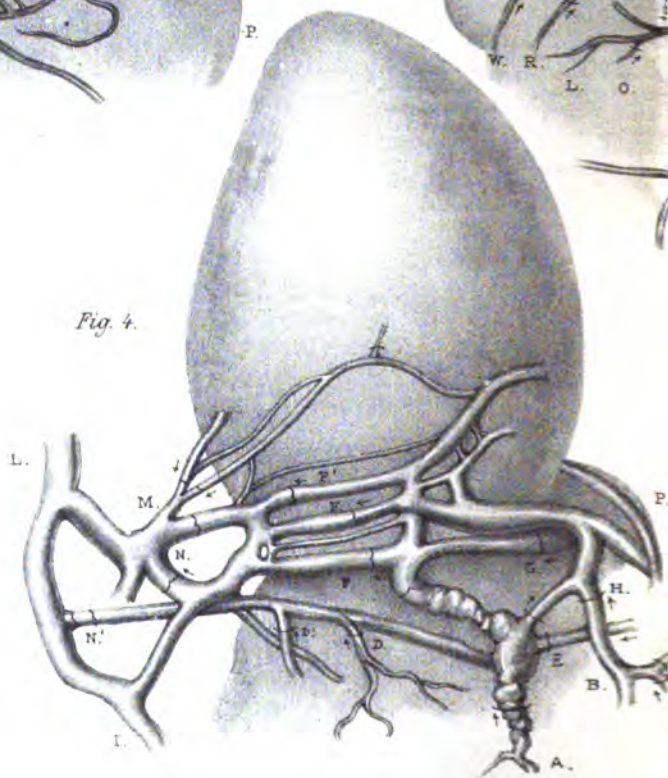


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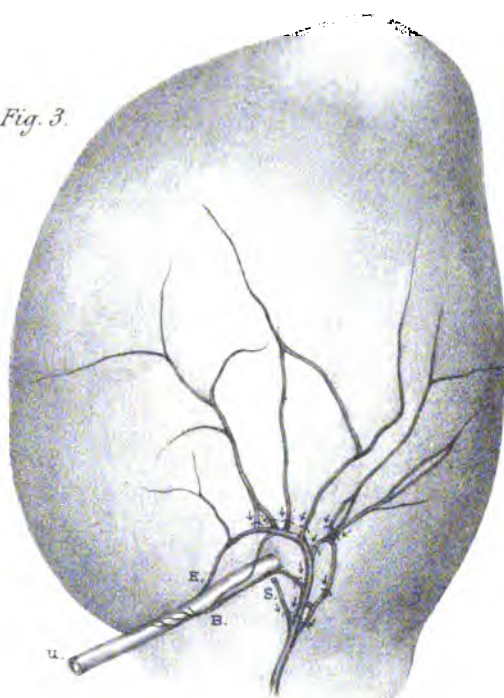
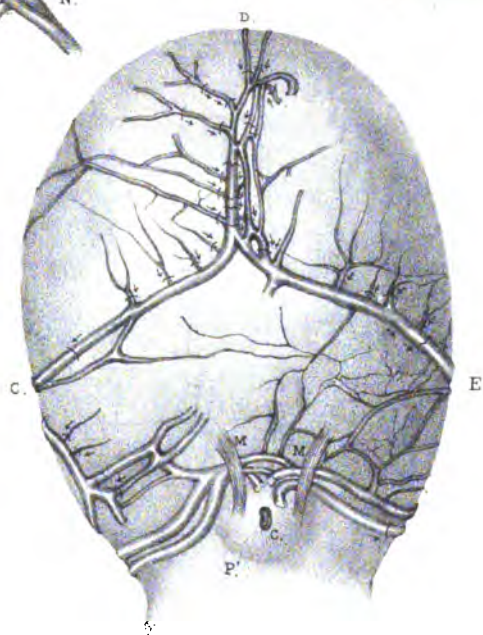
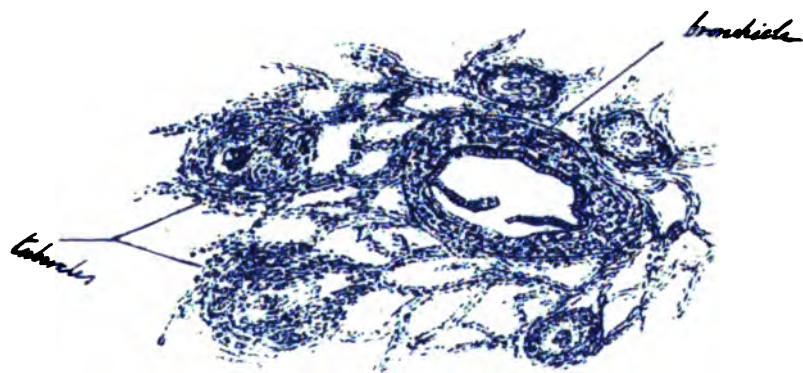
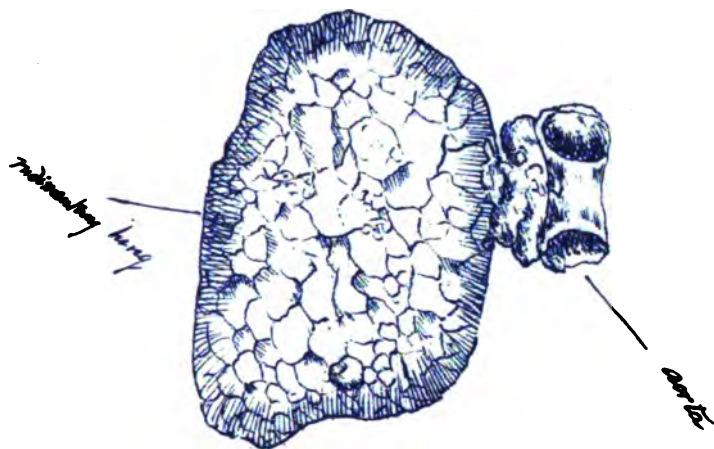


Fig. 5.





Microscopic section

Fig. 1.

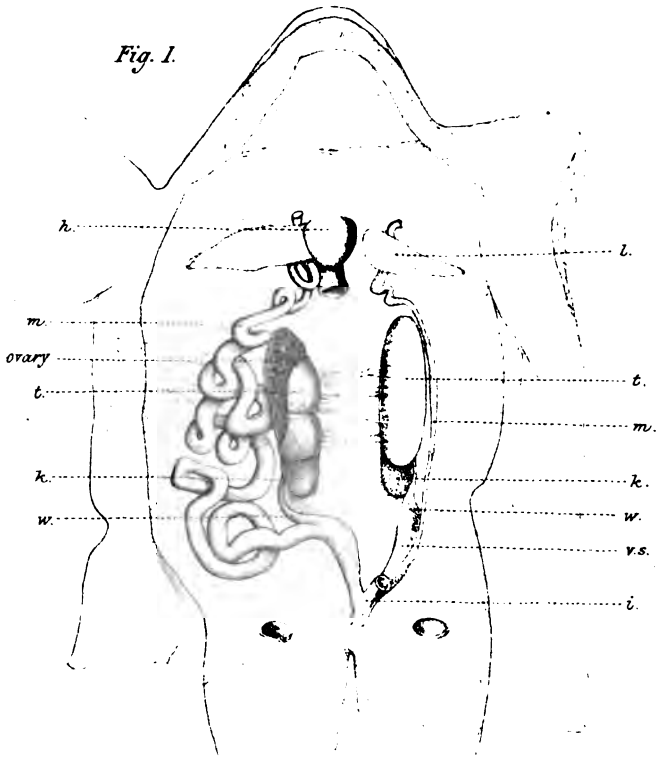
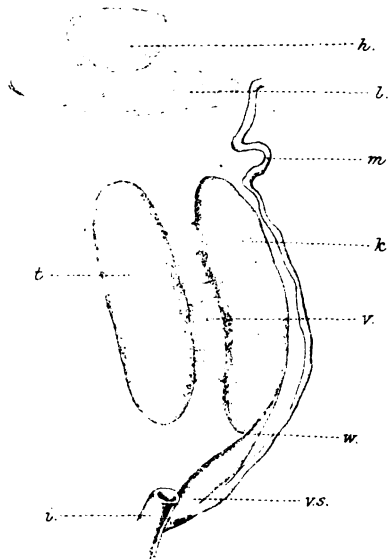


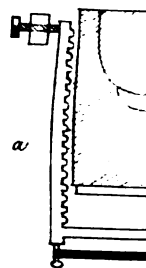
Fig. 2.





A

From photo*

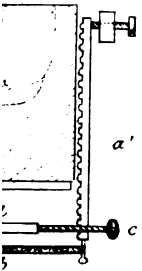




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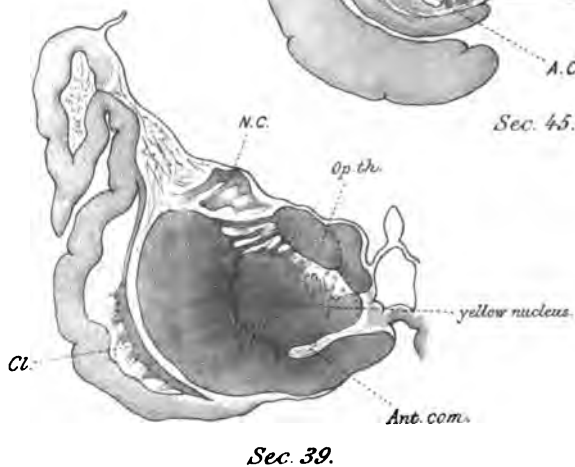
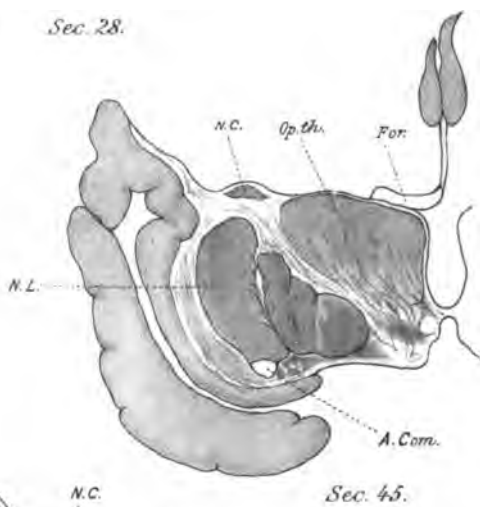
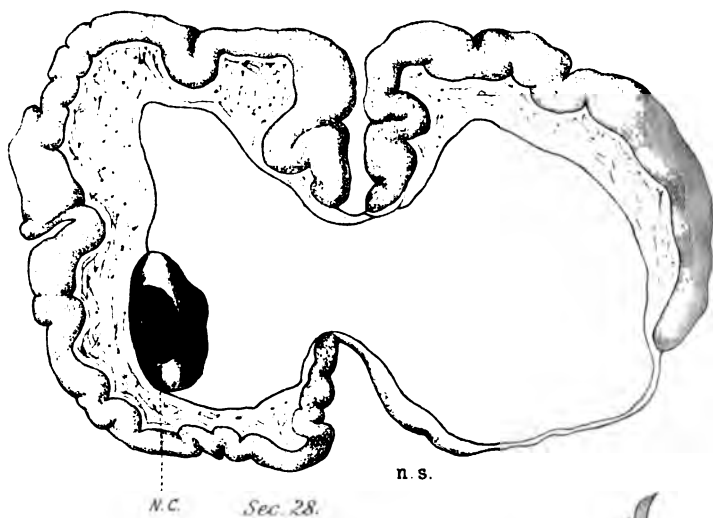


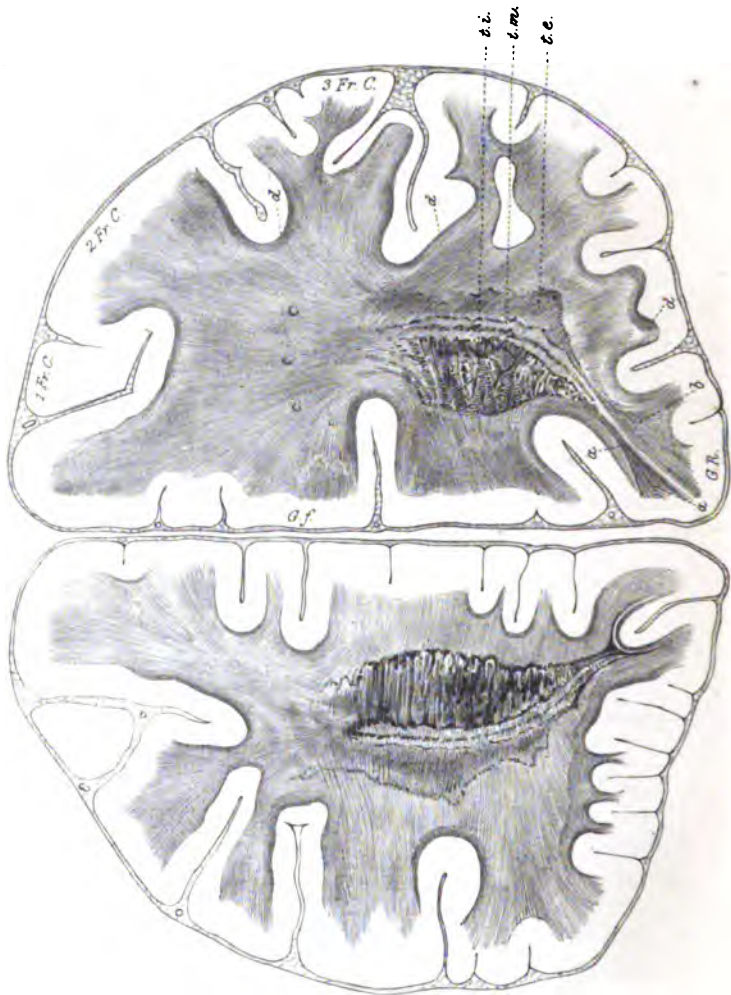
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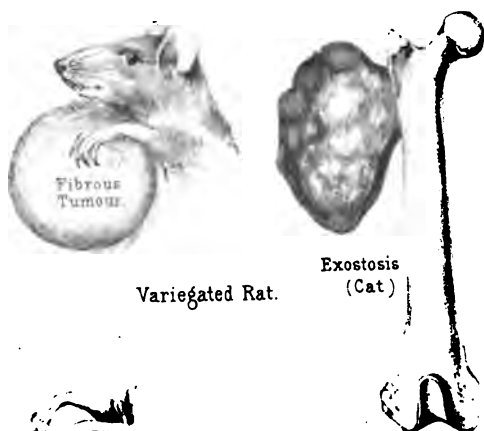


Fig. 3.

Fig. 13.

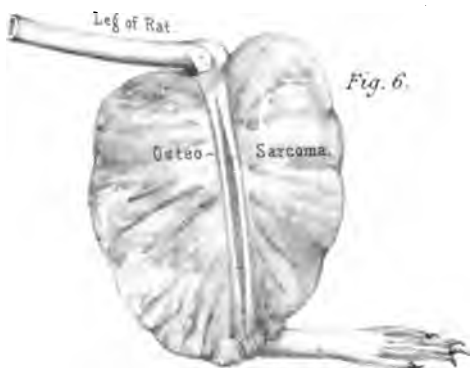


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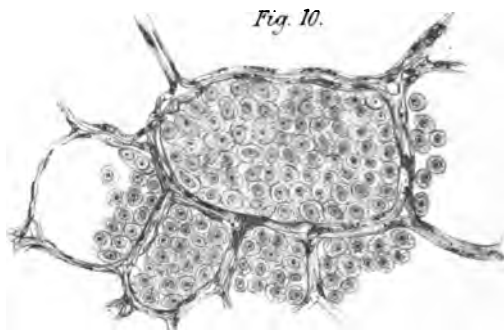


Fig. 11.





Fig. 5.



Fig. 4.

Fig. 15.



Head of Cock.

Fig. 14.

Eye of Sheep.

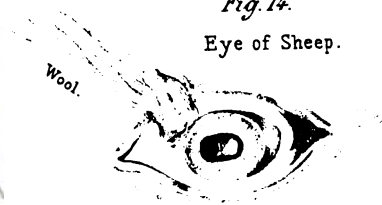


Fig. 9.



Fig. 12.

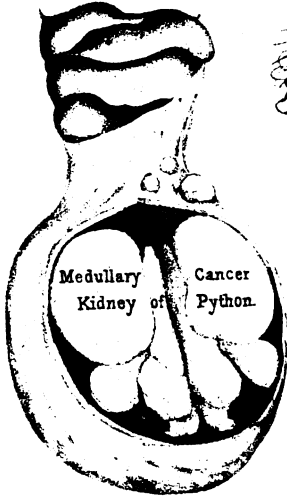


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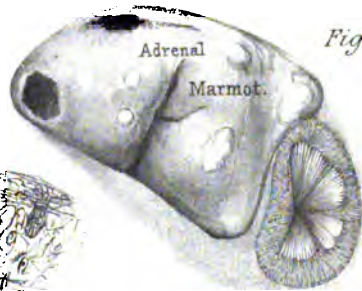


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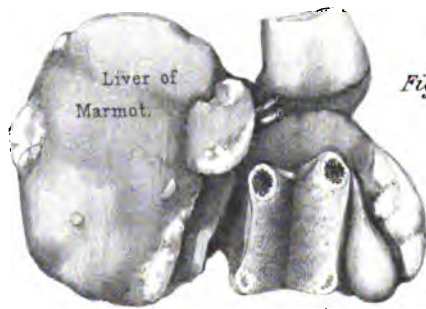


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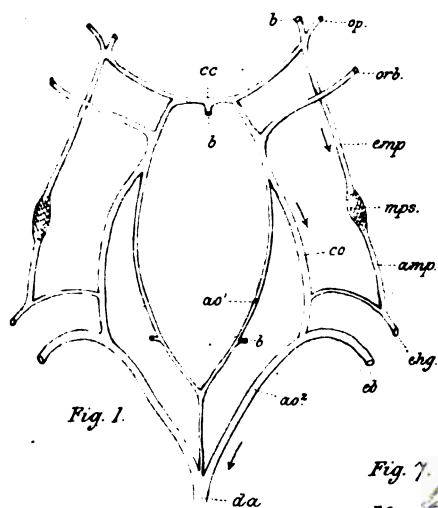


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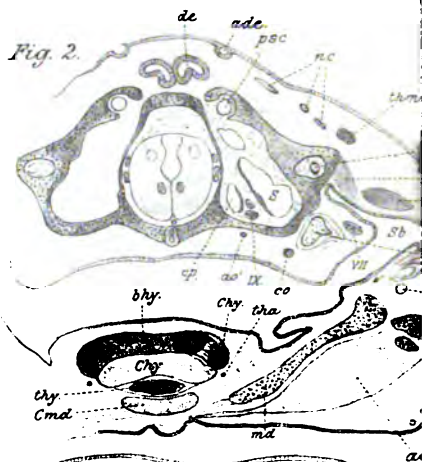


Fig. 2.

Fig. 6.



Fig. 7.

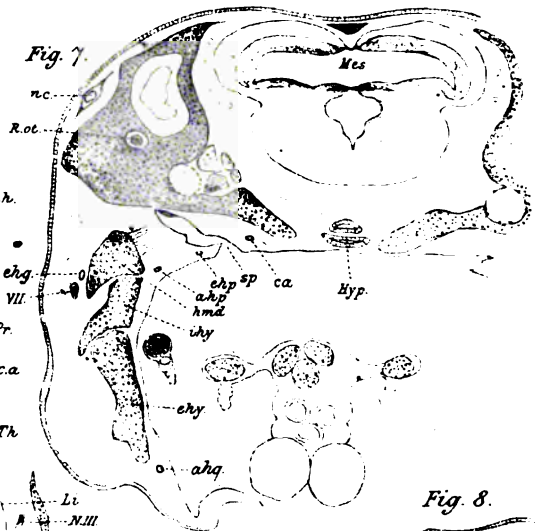


Fig. 8.



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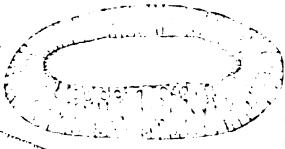


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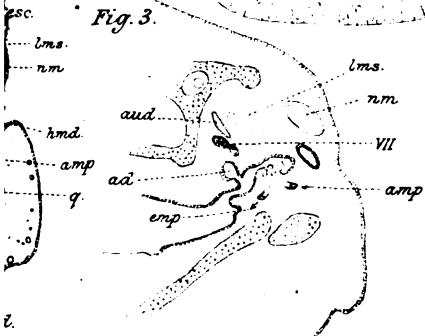


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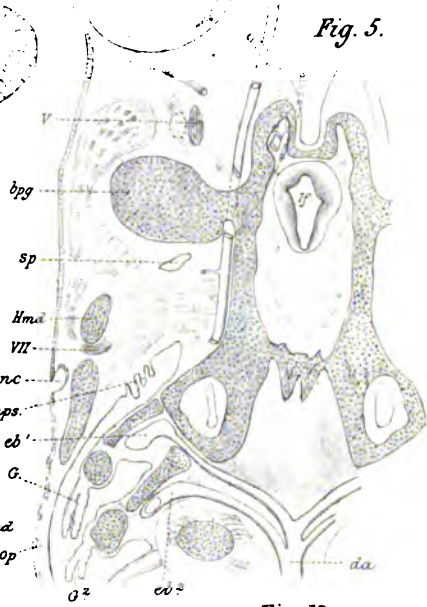


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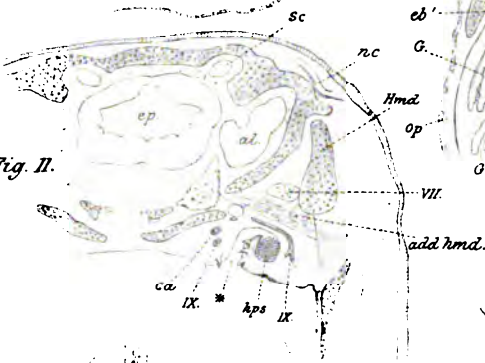


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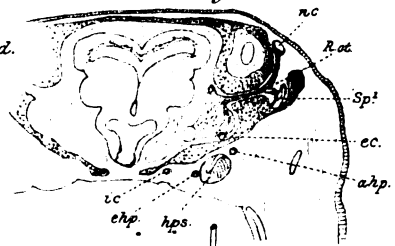


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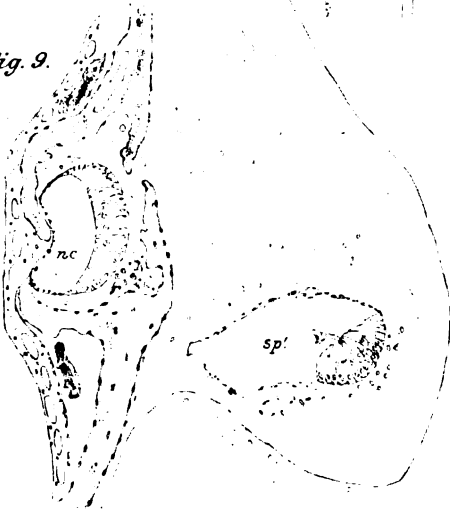
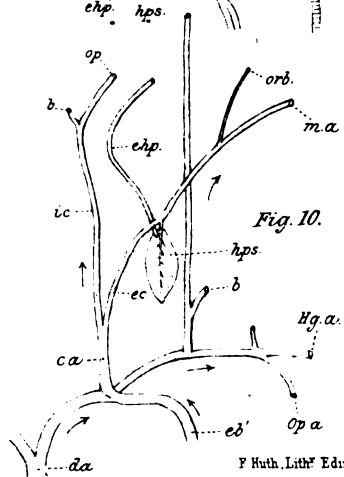


Fig. 10.





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